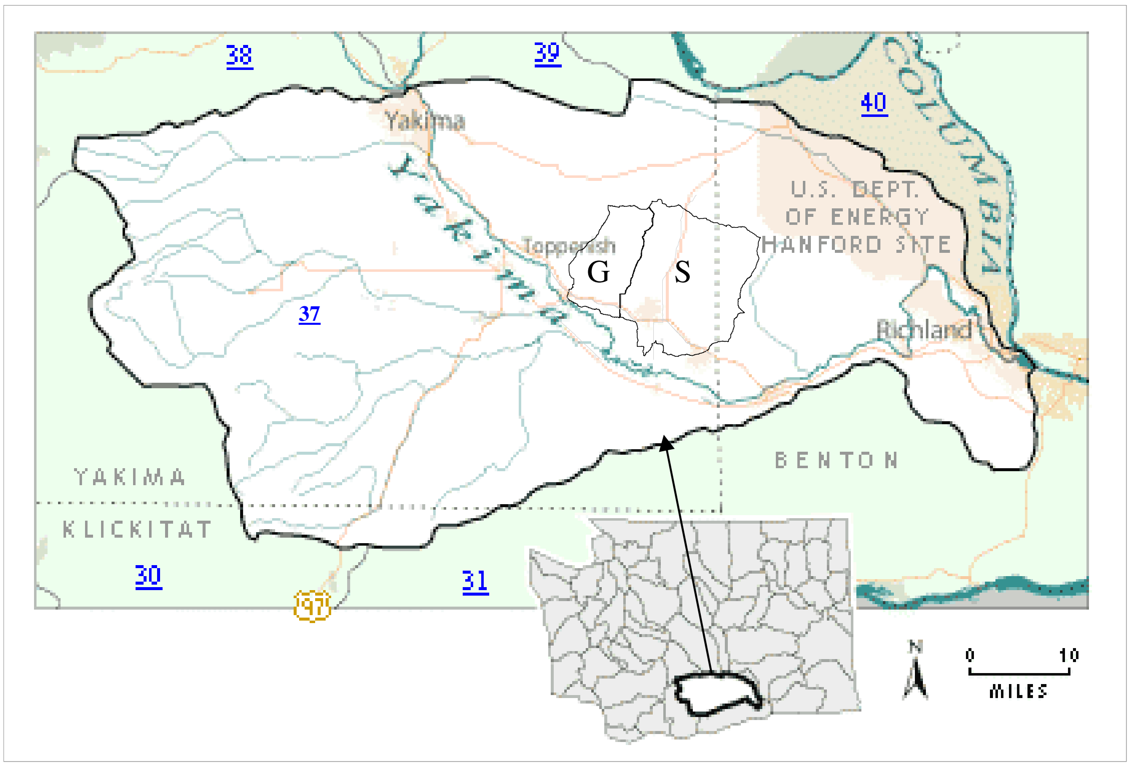
Water Quality in Sulphur Creek Wasteway and Granger Drain, 1997 to 2004



The lower Yakima River basin, Water Resource Inventory Area 37, showing Granger Drain watershed (G), and adjacent Sulphur Creek Wasteway watershed (S)

South Yakima Conservation District

January 2006

Water Quality in
Sulphur Creek Wasteway and Granger Drain,
1997 to 2004

Funded through the Centennial Clean Water Fund

South Yakima Conservation District
in collaboration with the Roza-Sunnyside Board of Joint Control

by

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Table of Contents

List of Figures

List of Tables

Acronyms

BMP	Best Management Practice
CFS	Cubic feet per second
Cfu/dL	Colony-forming units per deciliter, a measurement of fecal coliform concentrations
EQIP	Environmental Quality Incentives Program
Mg/L	milligrams per liter (equivalent to parts-per-million)
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Unit
RSBOJC	Roza-Sunnyside Board of Joint Control
SYCD	South Yakima Conservation District
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey

Acknowledgments

Without a long-term monitoring program that captures the variability within and between watersheds, the kinds of analyses completed for this report would not be possible, greatly reducing our ability to understand changing conditions in these watersheds. A report like this would not be possible without:

Roza-Sunnyside Board of Joint Control, for beginning and maintaining their sampling program.

South Yakima Conservation District Board of Supervisors, for continued willingness to ask questions that may have difficult answers.

Most importantly, the landowners in these watersheds who have improved their soil and water conservation practices.

Executive Summary

An earlier report, "*Conservation Practices and Water Quality Trends in Sulphur Creek Wasteway and Granger Drain Watersheds, 1997 to 2002*" by South Yakima Conservation District in collaboration with the Roza-Sunnyside Board of Joint Control, found substantial improvements in water quality in the Sulphur and Granger watersheds. Have the improvements continued through 2004?

Downward trends in concentrations of total suspended solids, total phosphorus, total Kjeldahl nitrogen, and fecal coliform in Granger Drain and Sulphur Creek Wasteway during the eight irrigation seasons from 1997 to 2004 continued to be statistically significant. Concentrations, loads, and yields of most constituents in most drains during 2003 and 2004 were generally comparable to 2002 and 2000.

However, there were several differences between the first four irrigation seasons, from 1997 to 2000, and the last four seasons, from 2000 to 2004:

- The rate of declines in concentrations, loads, and yields of most constituents was slower from 2000 to 2004 than previously.
- Declines were less consistent from 2000 to 2004 than previously; in some sub-basins, concentrations of some constituents increased. In contrast, from 1997 to 2000 concentrations of all constituents declined in all sub-basins, except nitrate in one Granger sub-basin.
- In general, from 1997 to 2000 the ranges of concentrations decreased substantially, except for nitrate. From 2000 to 2004, the ranges of concentrations generally stabilized or only narrowed slightly.
- From 1997 to 2000 the irrigation season concentrations of total suspended solids, total phosphorus, and fecal coliform were generally much higher than the non-irrigation season in both drains. Since 2000:
  - In Sulphur Creek Wasteway, irrigation season concentrations of total suspended solids and total phosphorus were **less than** non-irrigation season concentrations, while fecal coliform concentrations were comparable between seasons.
  - In Granger Drain, total suspended solids and fecal coliform concentrations during the irrigation season were higher than the non-irrigation season but with a smaller gap than before 2000; total phosphorus concentrations were comparable between seasons.

The Total Maximum Daily Load turbidity goal of 25 NTU was met in Sulphur Creek Wasteway from 2000 to 2004 but not met in Granger Drain in any year.

The combination of slower rates of improvement in some sub-basins, worsening conditions in other sub-basins, and slight or no decreases in the range of concentrations of most constituents during recent years suggests further improvements in water quality in these drains will be even more difficult to achieve than in the past.

Introduction

Sulphur Creek Wasteway and Granger Drain are two of the most important irrigation return drains to the Yakima River due to their relative contribution of suspended sediment, nutrients, and bacteria. The primary land-use in both watersheds is irrigated agriculture.

The declines in concentrations, loads and yields of suspended sediment, nutrients, and bacteria in these watersheds during the late 1990's were a major success story at local, state, and national levels. Local agencies, including the Roza-Sunnyside Board of Joint Control, South Yakima Conservation District, and WSU-Cooperative Extension who assisted growers with their conservation efforts, received an Environmental Excellence award from the Department of Ecology in 2004 on behalf of the farmers' efforts. The National Association of Conservation Districts wrote up the results in one of five success stories highlighting non-point pollution reduction efforts. Additionally, the Environmental Protection Agency described federally-funded projects in the lower valley as examples of non-point pollution success stories.

Have the improvements continued in the most recent years? To answer this question, the following report evaluates turbidity, suspended sediment, nutrient, bacteria, and discharge data from the Roza-Sunnyside Board of Joint Control from 1997 to 2004. South Yakima Conservation District analyzes this data to help provide local organizations and interested landowners with as current information as possible to allow development and prioritization of soil and water conservation efforts in response to changing environmental conditions.

Water Quality Results

RSBOJC routinely samples the major sub-basins within the Sulphur and Granger watersheds (Figure 1) and the mouths of these drains. The frequency of RSBOJC's routine sampling has varied over the years (Table 1). Most commonly, samples were obtained every other week during the irrigation season and monthly during the non-irrigation season. However, in 1997 sampling did not begin until June because the program was still in development. Also, in response to the Granger Drain Fecal Coliform Total Maximum Daily Load (TMDL), RSBOJC chose to increase their sampling frequency at the mouth of Granger Drain beginning in 2002.

As in previous years, samples were analyzed in RSBOJC's in-house laboratory for turbidity, total suspended solids, and fecal coliform. Samples were shipped to the Bureau of Reclamation laboratory in Boise, Idaho for total phosphorus, total Kjeldahl nitrogen, and nitrate+nitrite[1] analyses.

[1] The laboratory analysis method captures nitrate and nitrite; however, since earlier sampling efforts found negligible nitrite concentrations, text in the remainder of this report will refer only to nitrate.

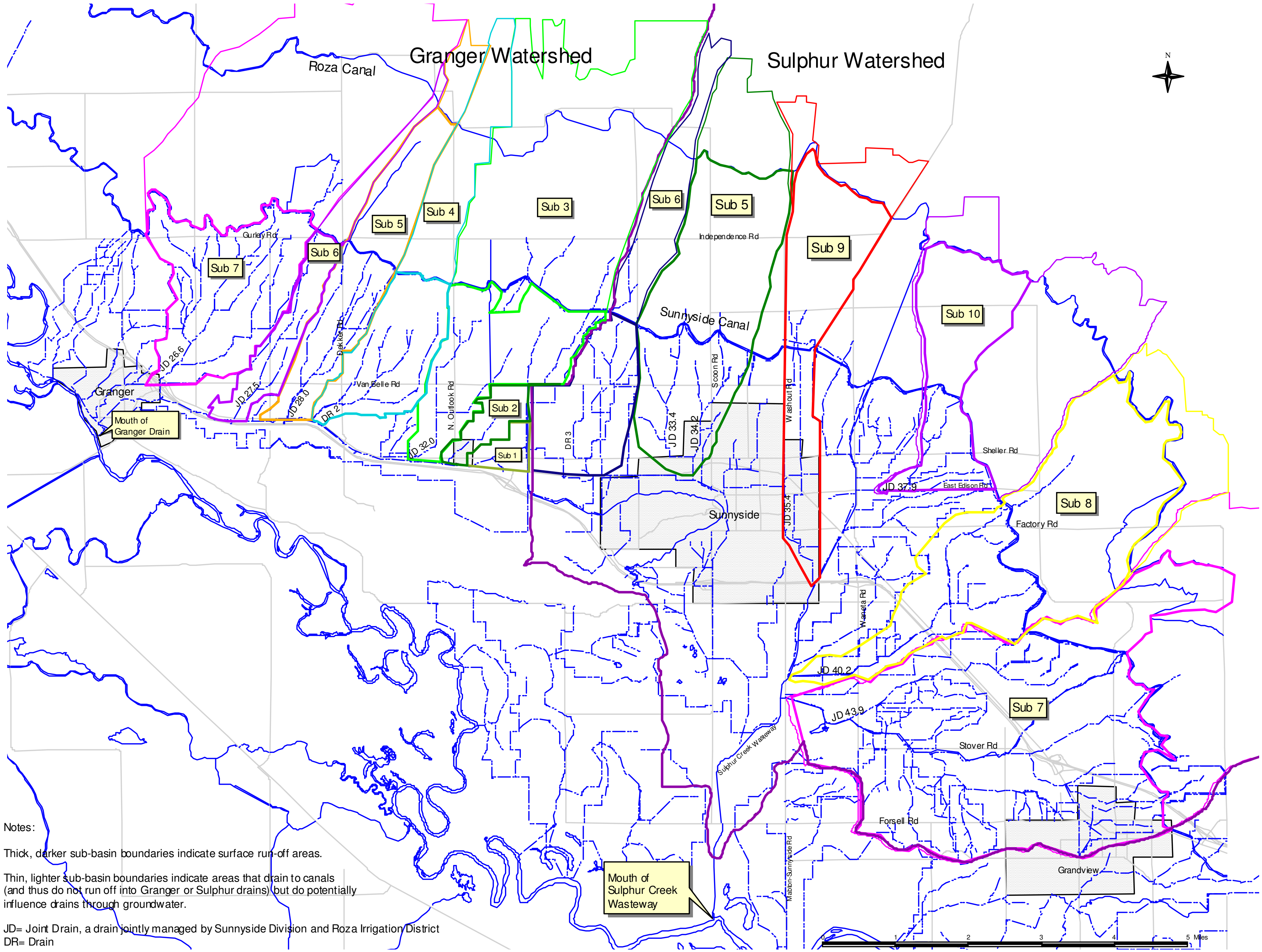


Figure 1. Granger and Sulphur sub-basins.

Table 1. **Sampling frequency.**

	Irrigation Season							
Year	1997	1998	1999	2000	2001	2002	2003	2004
Sulphur Creek Wasteway	Every other week							
Sulphur sub-basins	Not sampled		Every other week					
Granger Drain	Every other week						Weekly	
Granger sub-basins	Every other week							
	Non-Irrigation Season							
Year	1997	1998	1999	2000	2001	2002	2003	2004
Sulphur Creek Wasteway	Monthly							
Sulphur sub-basins	Not sampled		Monthly					
Granger Drain	Monthly					Every other wk	Weekly	Every other wk
Granger sub-basins	Monthly							

Irrigation Season

General Trends and Observations

The amount of water available for irrigation throughout the years from 1997 to 2004 was fairly constant except for the 2001 drought. During 2001, the Roza Irrigation District, a junior water right holder, received only 37% of its normal water supply. The Sunnyside Division, a senior water right holder, received 85% of its normal water supply. In the remaining years, the amount of normal water supply available for both districts ranged from 92 to 100 percent[2]. The effect of the drought on water quality is discussed later in this report under individual parameters.

Trend analysis using a seasonal Kendall trend analysis was conducted for all constituents at the mouth of Sulphur Creek Wasteway and Granger Drain from 1997 to 2004 during the irrigation season. Downward trends were statistically significant ($p<0.01$) for concentrations of total suspended solids, total phosphorus, and fecal coliform in both drains. The downward trend of total Kjeldahl nitrogen was statistically significant ($p<0.01$) in Granger Drain and Sulphur Creek Wasteway ($p=0.02$). There was no evidence of a statistically significant trend for nitrate concentrations in either drain.

The percent declines in median concentrations, loads, and yields of suspended sediment, nutrients, and bacteria during the irrigation season were generally greater from 1997 to 2000 than from 2000 to 2004 (Table 2). The year 2000 was chosen as a break point in comparing groups of years because several constituents at many sites showed lower variability and decreased rate of decline beginning in 2000.

[2] Per conversation with Chris Lynch, river operations manager, Bureau of Reclamation, on March 29, 2006: the pro-rationing rate was 100% in 1997 to 2000 and 2002, 37% in 2001, and 92% in 2003 and 2004.

Table 2. **Percent decreases in concentrations, discharge, and loads from 1997 to 2000 and 2000 to 2004 irrigation seasons.**

Granger Drain	Turbidity	Total Suspended Solids	Total Phosphorus	Nitrate + Nitrite	Total Kjeldahl Nitrogen	Fecal coliform	Discharge
Median concentrations or values							
% decrease 1997 to 2000	77	81	73	12	69	48	7
% decrease 2000 to 2004	23	29	2	-3	-19	56	13
Median loads and yields							
% decrease 1997 to 2000	n/a	84	79	17	67	52	7
% decrease 2000 to 2004	n/a	27	-4	10	-7	59	13

Sulphur Creek Wasteway	Turbidity	Total Suspended Solids	Total Phosphorus	Nitrate + Nitrite	Total Kjeldahl Nitrogen	Fecal coliform	Discharge
Median concentrations or values							
% decrease 1997 to 2000	75	77	65	35	54	73	-16
% decrease 2000 to 2004	23	49	-7	-60	-27	17	39
Median loads and yields							
% decrease 1997 to 2000	n/a	71	57	29	71	35	-16
% decrease 2000 to 2004	n/a	62	29	5	44	33	39

Negative values indicate increased concentrations.

In the Granger sub-basins, from 1997 to 2000 all sites improved for all constituents except nitrate in Granger sub-basin 4 (Figure 2). Monitoring did not begin in the Sulphur sub-basins until 1999.

From 2000 to 2004, the only constituent for which all 12 sites improved was fecal coliform (Figure 2). Total suspended solids concentrations increased at four sites, total phosphorus at six sites, and total Kjeldahl nitrogen and nitrate at five sites. The percent increase between years varied widely from negligible to a 211% increase in Granger sub-basin 4, where total suspended solids concentrations increased from a median of 46 milligrams per liter (mg/L) in 2000 to 142 mg/L in 2004. Most increases ranged from 15 to 50 percent.

The cause of the decreased rate of improvement is unknown. Two possible reasons include (1) the diminishing rate of return characteristic of many environmental improvements or (2) an unknown but theoretically possible decreased rate of implementing non-government funded conservation practices. Other possible reasons likely could be added by those familiar with these watersheds. But we have no data to help determine the actual reason for the decline.

SYCD's earlier report, *Conservation Practices and Water Quality Trends in Sulphur Creek Wasteway and Granger Drain Watersheds, 1997 to 2002*, included an in-depth analysis comparing all known government-funded BMP implementation rates within the Sulphur and Granger watersheds against water quality improvement rates. There was no direct correlation between the two rates. The report suggested the relationship was masked by other variables such as privately-funded BMP implementation or varying effectiveness of government-funded BMPs. The report noted that other factors

Negative numbers indicate increased concentrations.

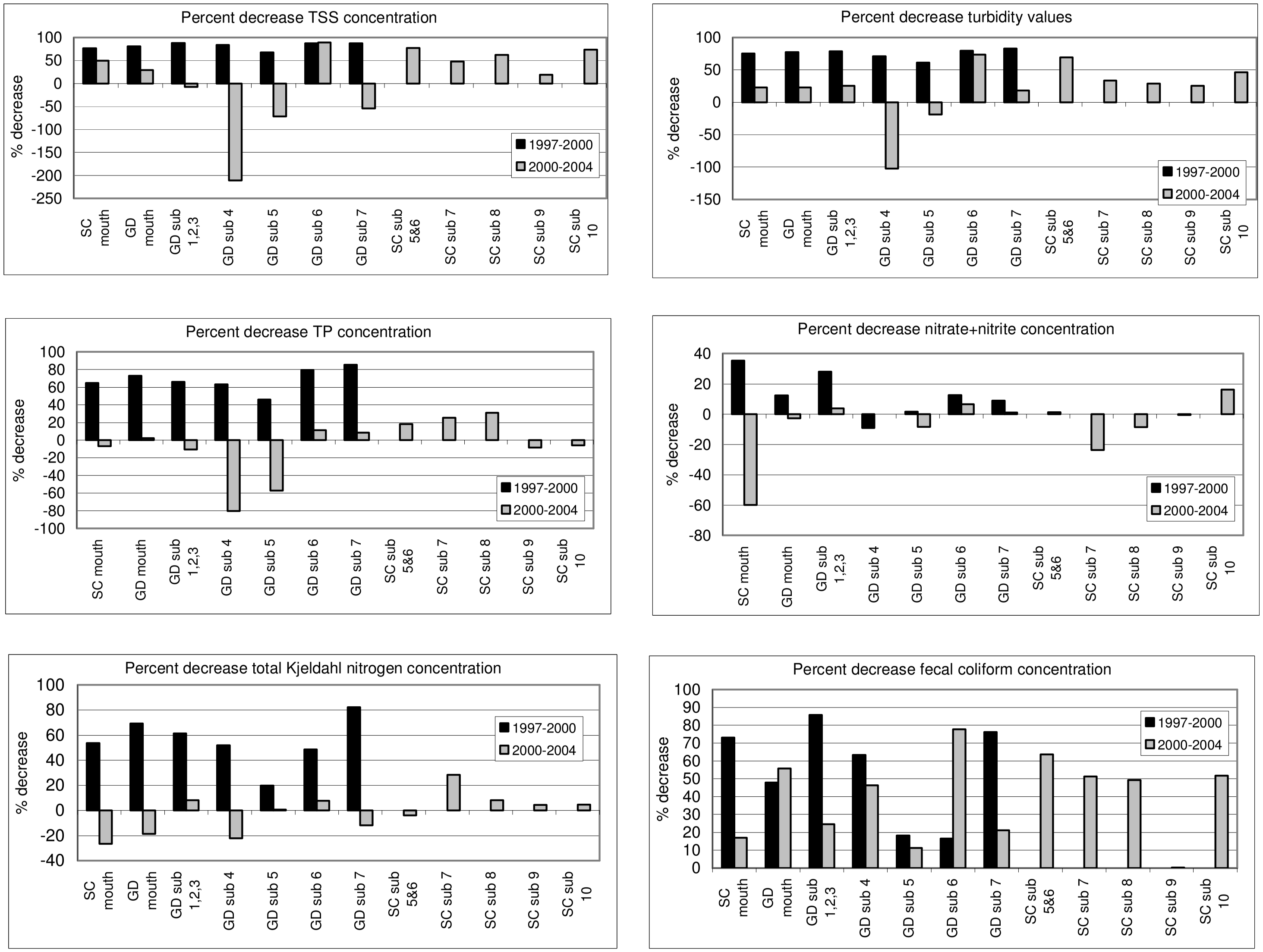


Figure 2. Percent change from 1997 to 2000 and 2000 to 2004 irrigation seasons in Sulphur and Granger watersheds.

potentially affecting water quality but not considered include changing crop types, on-farm water delivery rates, the rate of piping irrigation return drains, and decreased transport efficiencies in drains with substantial aquatic plant growth.

SYCD discontinued tracking implementation rates of government-funded best management practices (BMPs) in these watersheds in 2002 after the grant funding for that task ended. BMP implementation rates within these watersheds during 2003 and 2004 are unknown. One indicator of BMP rates may be the number of landowners participating in the Natural Resources Conservation Service's Environmental Quality Incentives Program (EQIP), which has helped many growers replace inefficient rill irrigation with more efficient sprinkler or drip systems. Participation in EQIP in Yakima County has varied over the years (Table 3) but has been consistently higher in the last four years than in earlier years, so EQIP participation rates are unlikely to explain the slower rate of water quality improvement.

Table 3. Environmental Quality Incentives Program contracts in Yakima County.

Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	***total***
Number of contracts	15	12	15	26	51	39	38	43	*239*

Variability

At the mouths of the drains, the ranges in concentrations of total suspended solids, total phosphorus, total Kjeldahl nitrogen, and fecal coliform throughout the irrigation season narrowed substantially from 1997 to 2000. From 2000 to 2004, the range of concentrations of any single constituent tended to remain similar, except for fecal coliform concentrations in Granger Drain, which continued to decline. From 2000 to 2004, the range of concentrations for these constituents was generally narrower in Sulphur Creek Wasteway than in Granger Drain (Figures 3, 4).

The range of nitrate concentrations in either drain did not consistently decrease or increase from irrigation season to irrigation season but was frequently greater in Sulphur Creek Wasteway than Granger Drain. The higher variability of nitrate concentrations in Sulphur Creek Wasteway could be a reflection of the variability in the amount of canal water entering the wasteway.

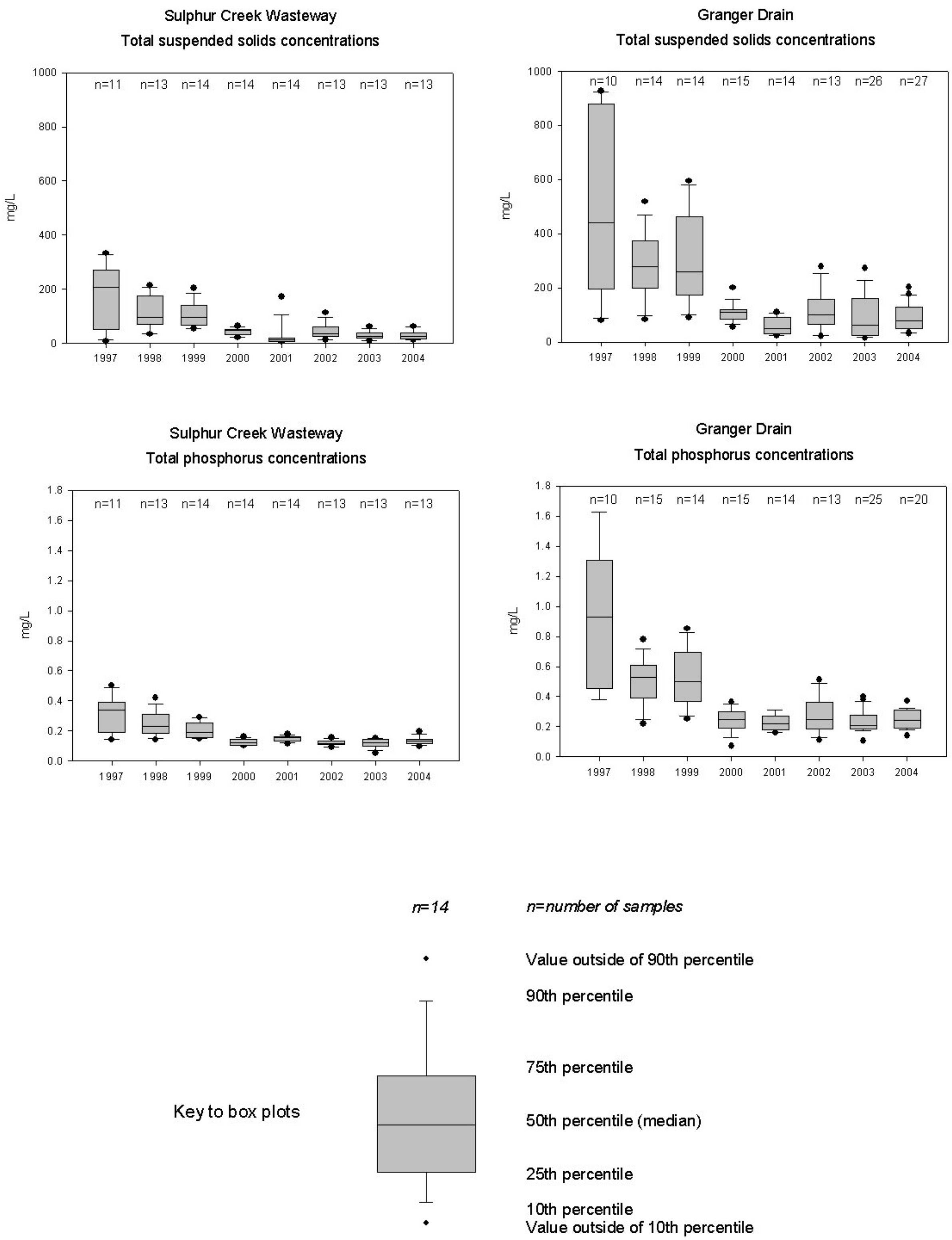


Figure 3. **Total suspended solids and total phosphorus concentrations in Sulphur Creek Wasteway and Granger Drain, 1997 to 2004 irrigation seasons.**

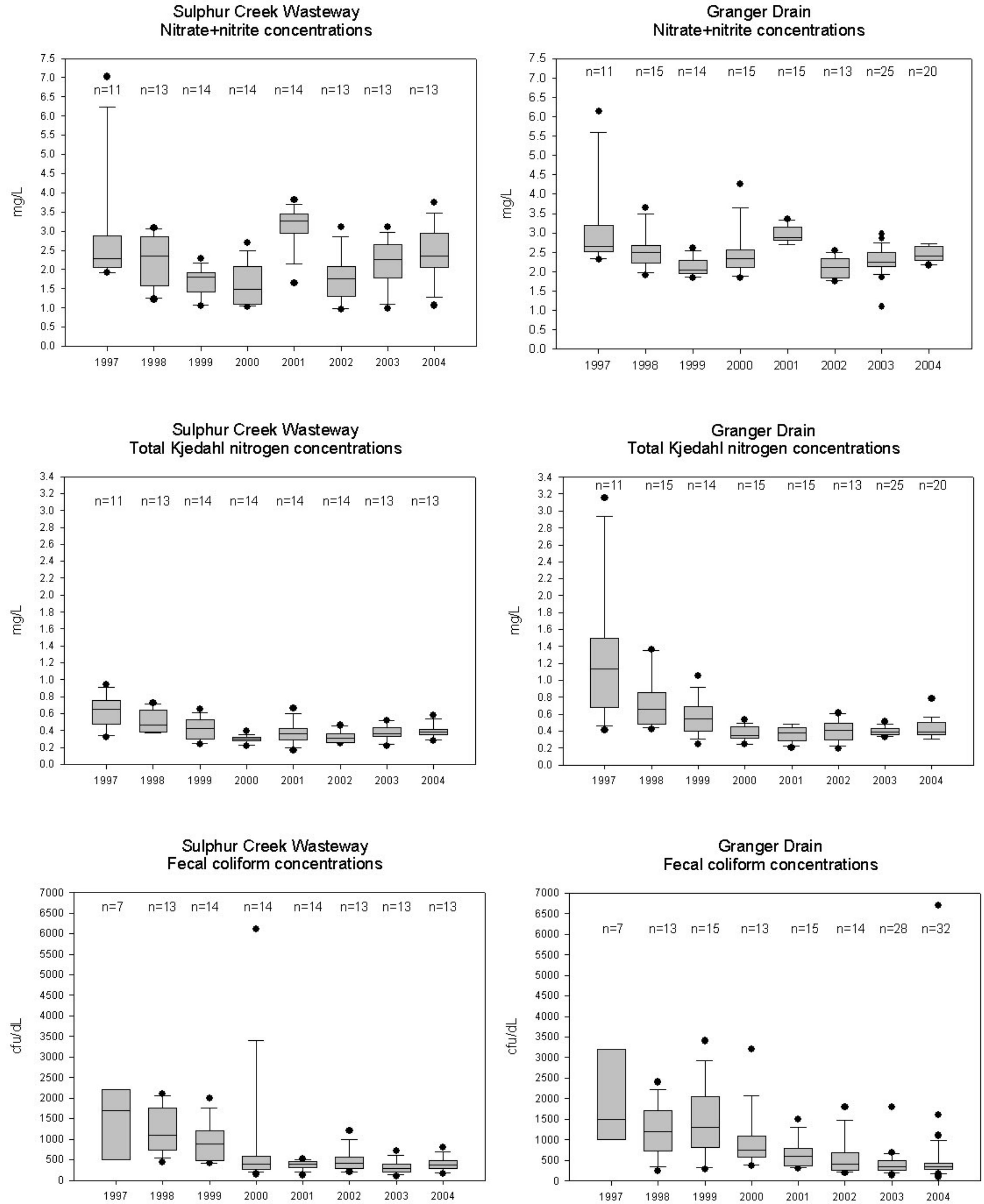


Figure 4. Nitrate+nitrite, total Kjeldahl nitrogen, and fecal coliform concentrations in Sulphur Creek Wasteway and Granger Drain, 1997 to 2004 irrigation seasons.

Specific Parameters

How did the most recent irrigation seasons of 2003 and 2004 compare to previous years? Were there concerning anomalies or were these recent years fairly typical?

Discharge

Discharge in 2003 and 2004 followed the same pattern as in 1997 to 2002 -- the relative ranking of highest-to-lowest discharge rates among sub-basins stayed nearly the same from year to year (Figure 5). The impact of the 2001 drought is seen in reduced discharges from both drains. Yields were generally between 0.5 and 1 ac-ft/ac/190-day season in the sub-basins in both watersheds.

Turbidity and Total Suspended Solids

Median total suspended solids concentrations (Figure 6A&E) and turbidity values (Figure 7) were lower at the mouth of Sulphur Creek Wasteway than Granger Drain in all eight irrigation seasons. The mouth of Sulphur Creek Wasteway met the 2002 TMDL goal of 25 NTU at the 90th percentile from 2000 to 2004 (Figure 7). The 2007 TMDL goal of 25 NTU in the sub-drains was met by two Sulphur sub-basins in 2000, three sub-basins in 2001, 2002, and 2004, and all monitored sub-basins in 2003. The mouth of Granger Drain continued to not meet the 2002 goal.

Because Sulphur Creek Wasteway received diluting water from the canals, it would be expected to have lower concentrations of total suspended solids than Granger Drain. However, even the sub-basins within Sulphur watershed, which do not receive substantial amounts of canal water, had lower 75th and 90th percentile values than Granger sub-basins (Figure 8).

Although loads of suspended sediment continued to generally decline at the mouth of Granger Drain and Sulphur Creek Wasteway (Figure 6B&F), declines were not as consistent as from 1997 to 2000. Loads increased in 2002 compared to 2001, a reflection of drought-induced low loads in 2001. But median loads from both drains also increased from 2003 to 2004 -- non-drought years. In Sulphur Creek Wasteway, the increased load was due to increased discharge. But in Granger Drain, the increased load was due to an increase in the median total suspended solids concentration, which increased from 66 mg/L to 77 mg/L, resulting in a median load increase from 8.4 to 11.4 tons per day.

Loads from all Sulphur sub-basins were less in 2004 than 2000 (Figure 6C). In contrast, loads from all Granger sub-basins were slightly greater in 2004 than 2000 (Figure 6G). In the intervening years, Granger sub-basin loads sometimes increased, sometimes decreased, and at other times stayed nearly the same – unlike from 1997 to 2000 when loads decreased in almost every irrigation season from every sub-basin.

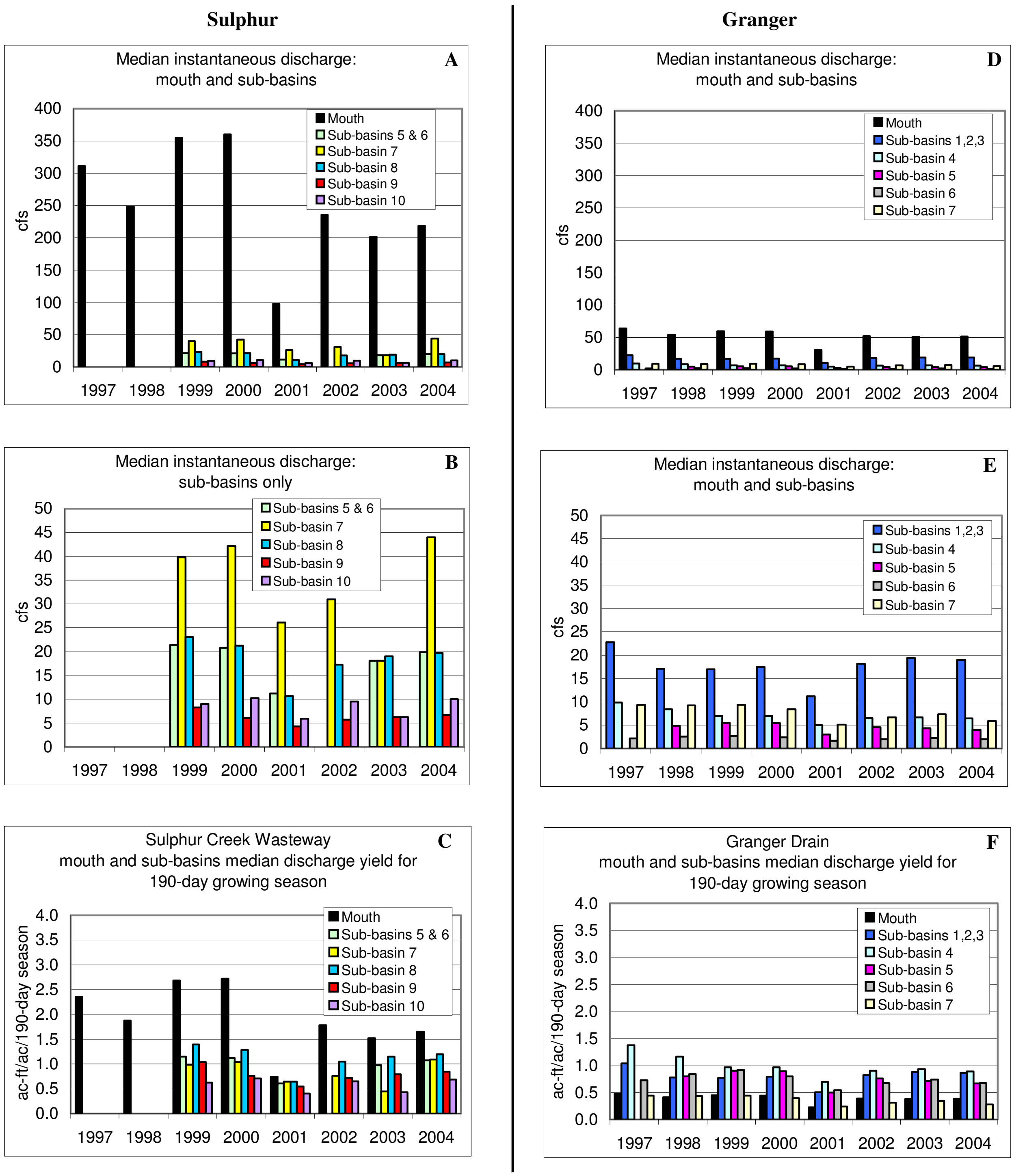


Figure 5. Instantaneous discharge and yields of water from irrigation return drains, Sulphur and Granger watersheds, 1997 to 2004 irrigation seasons.

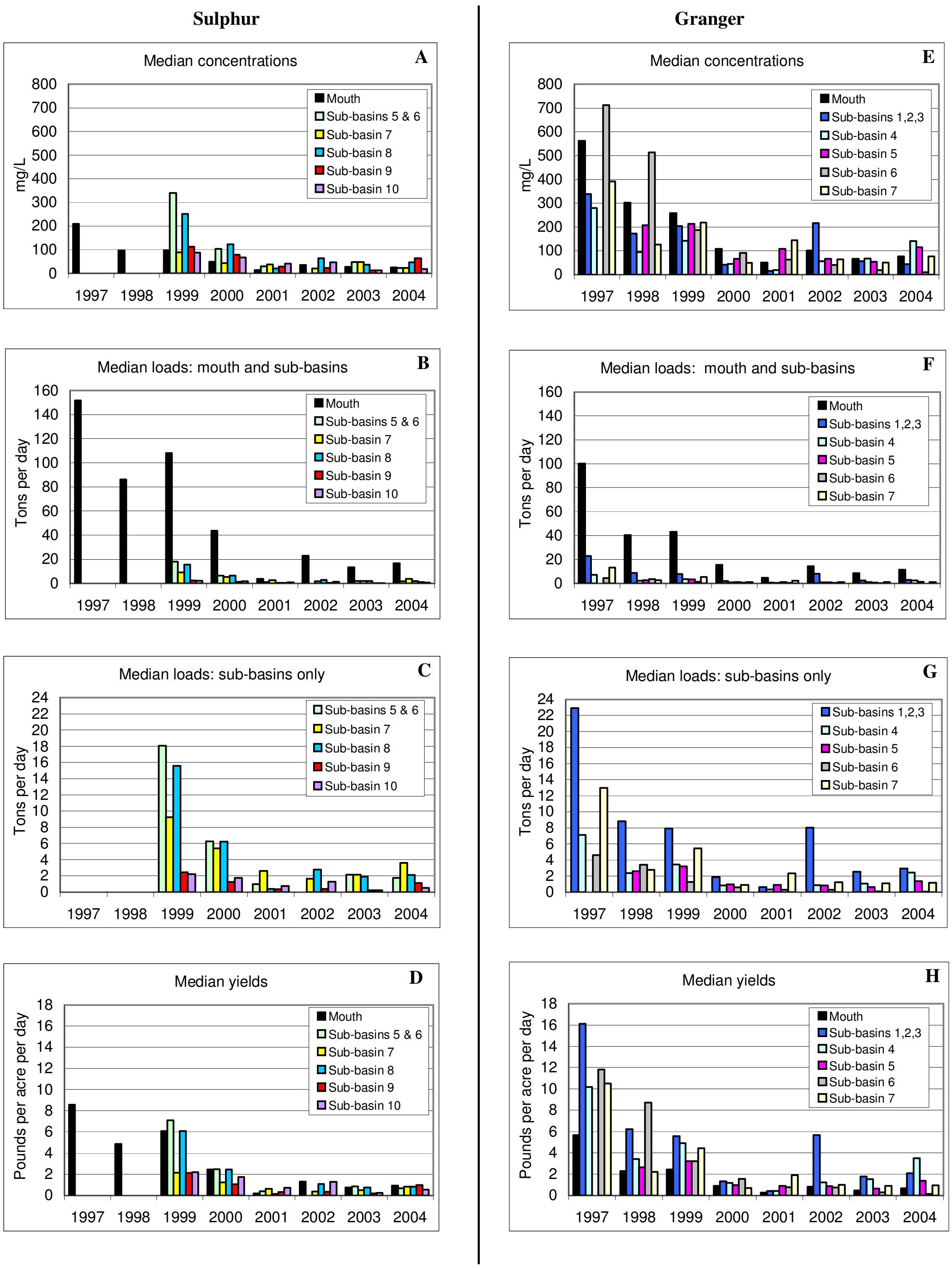
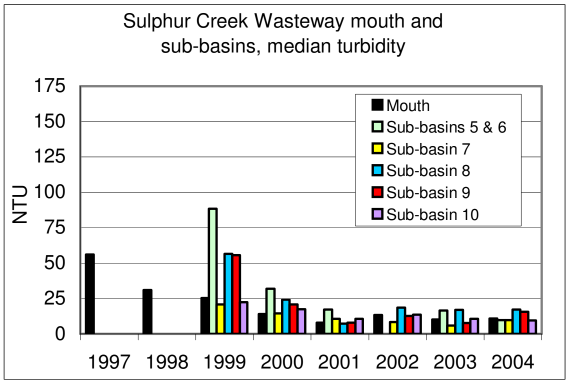
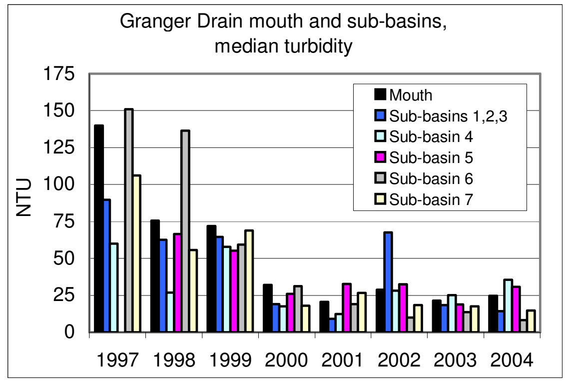
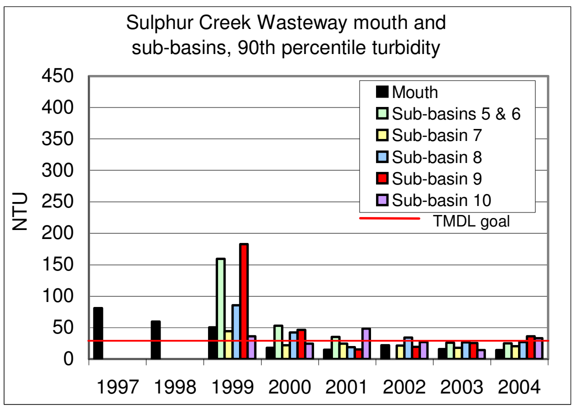


Figure 6. Total suspended solids: median concentrations, loads and yields, Sulphur and Granger watersheds, 1997 to 2004 irrigation seasons.





Note differences in scale between charts of medians, above, and the 90th percentiles, below.



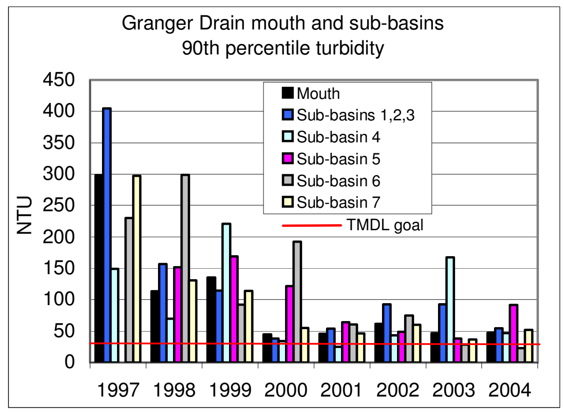


Figure 7. Turbidity: median and 90th percentile values, Sulphur and Granger watersheds, 1997 to 2004 irrigation seasons.

Since 2001, median yields were consistently less than 1.5 pounds per acre per day throughout the Sulphur watershed (Figure 6D). Since 2000, yields from Granger Drain were less than one pound per acre per day (Figure 6H). Yields from Granger sub-basins were generally less than 1.5 pounds per acre per day; however, in each irrigation season since 2000 at least one sub-basin exceeded 1.5 pounds, sometimes substantially.

Nutrients

Concentrations, loads, and yields of nutrients in 2003 and 2004 irrigation seasons were generally similar to 2000 and 2002. The drought year of 2001 resulted in decreased loads of most constituents primarily due to decreased discharge.

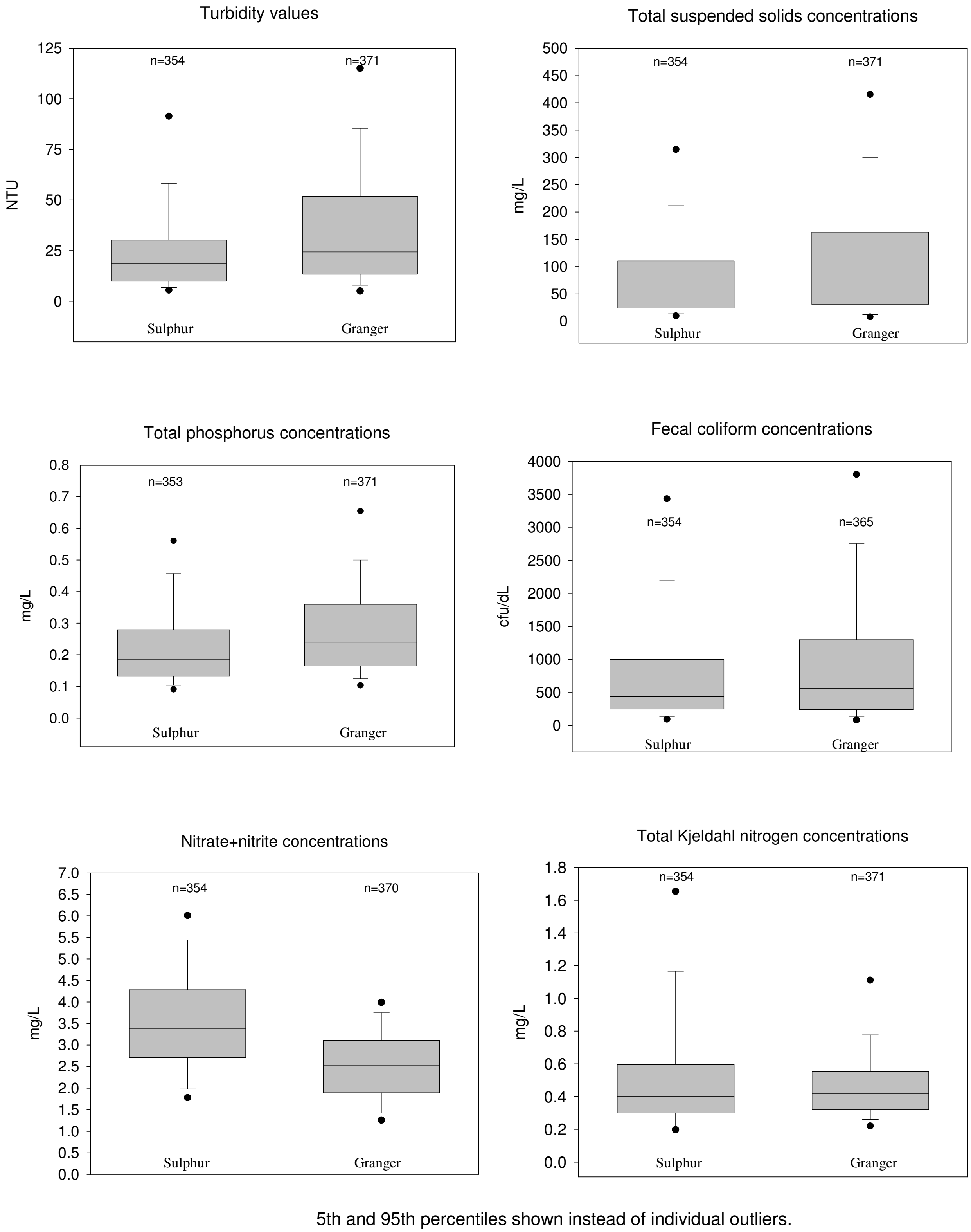


Figure 8. Concentrations of selected constituents, Sulphur and Granger sub-basins, 1999 to 2004 irrigation seasons.

Total Phosphorus

Median total phosphorus concentrations throughout the Sulphur watershed were relatively stable since 2000 (Figure 9A), ranging narrowly from 0.1 to 0.25 mg/L. Median concentrations throughout the Granger watershed since 2000 (Figure 9E) had a slightly wider and higher range, from 0.13 to 0.37 mg/L.

Median loads of phosphorus from Granger Drain and Sulphur Creek Wasteway did not consistently decline in recent irrigation seasons (Figure 9B&F). Loads increased in 2002, a reflection of drought-induced low loads in 2001, but also increased from 2003 to 2004 at the mouths of both drains, a result of increased discharge from Sulphur Creek Wasteway and slightly increased concentrations in Granger Drain.

In the sub-basins, median loads also no longer consistently declined since 2000 (Figure 9C&G). Median loads in all Sulphur sub-basins decreased from 2000 to 2002 but increased from 2003 to 2004. Within Granger sub-basins, the load from combined sub-basins 1,2,3 increased sharply in 2002 compared to 2000, declined through 2004 but remained higher in 2004 than 2000. Loads from sub-basin 4 increased gradually from 2000 through 2004. Loads in sub-basins 5, 6, and 7 remained comparable during the 2000 to 2004 irrigation seasons.

Median phosphorus yields were comparable from 2002 through 2004 throughout the Sulphur watershed while yields throughout the Granger watershed were more variable, increasing in some sub-basins but remaining comparable in others (Figure 9D&H).

Nitrate

There was no consistent pattern in nitrate concentrations from 1997 to 2004 throughout the Sulphur and Granger watersheds (Figure 10A&E).

Median nitrate loads (Figure 10B&F) followed a pattern similar to discharge (Figure 5A&D).

Yields throughout Granger watershed were fairly consistent since 1998 (Figure 10H). In Sulphur, there was more variability between irrigation seasons but the highest-to-lowest ranking between the sub-drains remained similar (Figure 10D). Sub-basins 7 and 10 had unusually low yields in 2003 due to a combination of decreased nitrate concentrations and decreased discharge in 2003.

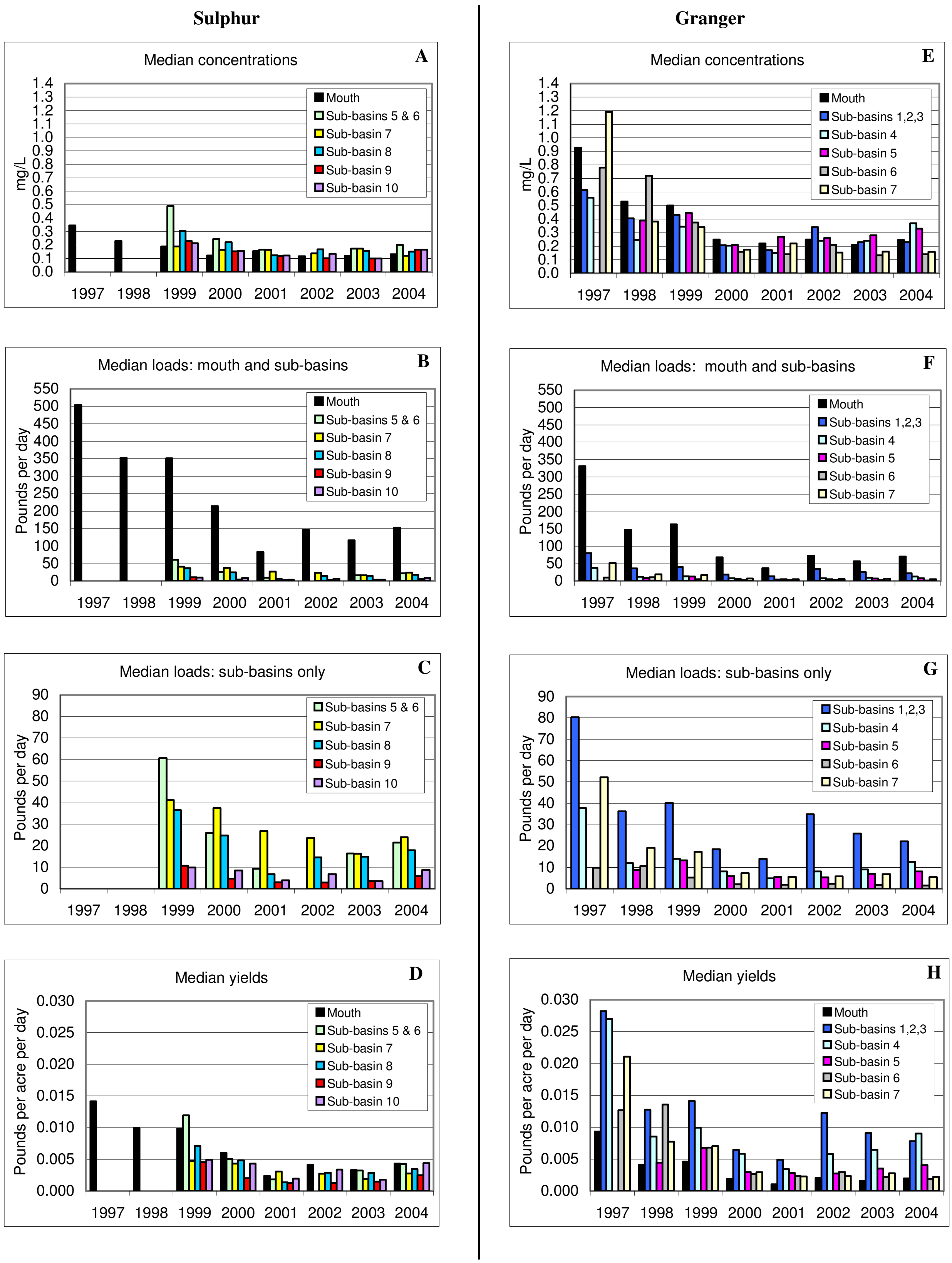


Figure 9. Total phosphorus: median concentrations, loads and yields, Sulphur and Granger watersheds, 1997 to 2004 irrigation seasons.

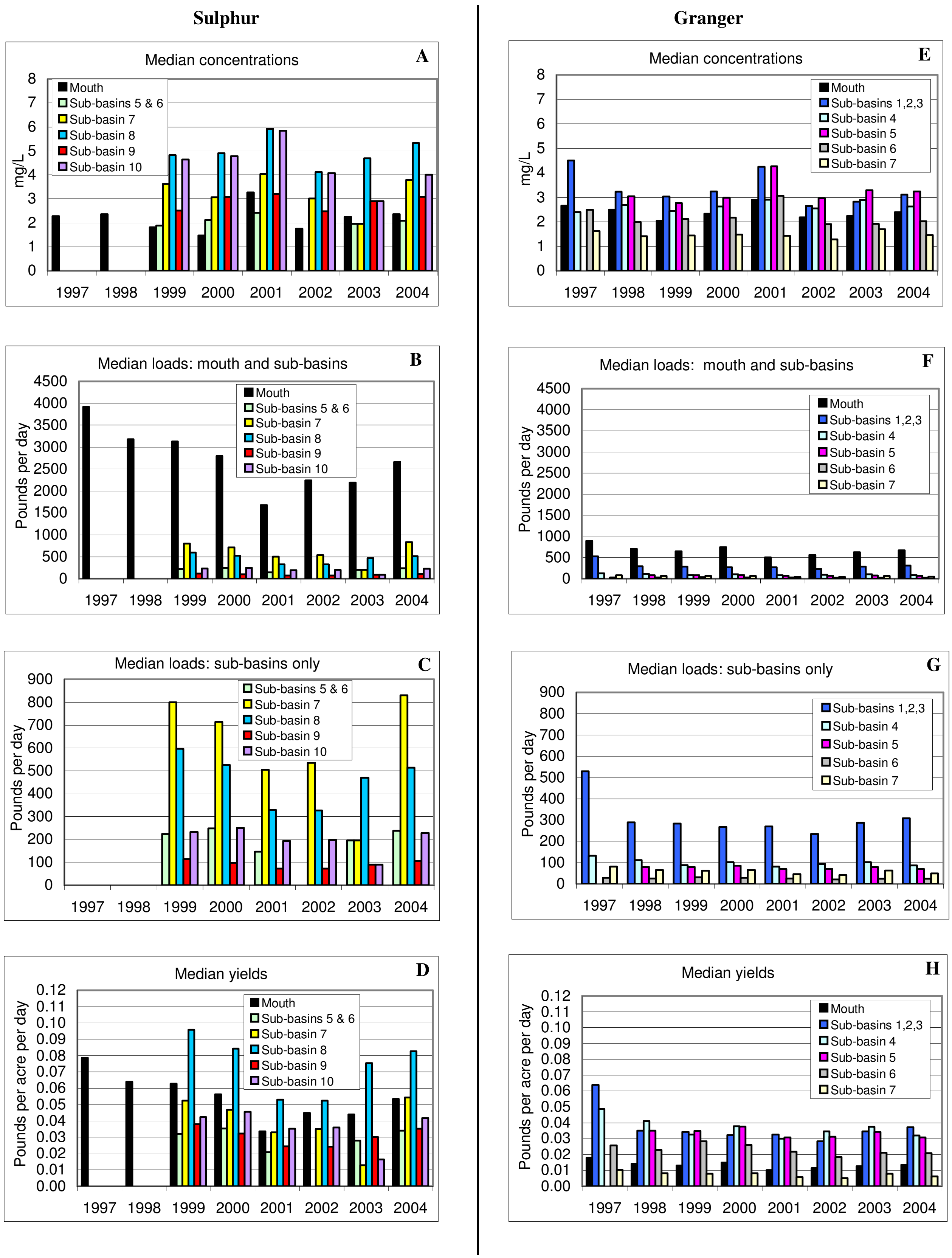


Figure 10. Nitrate+nitrite: median concentrations, loads and yields, Sulphur and Granger watersheds, 1997 to 2004 irrigation seasons.

Total Kjeldahl Nitrogen

Median concentrations of total Kjeldahl nitrogen (organic nitrogen plus ammonia) throughout the Sulphur and Granger watersheds were roughly comparable since 2000 (Figure 11A&E). Median concentrations during these irrigation seasons ranged from 0.20 to 0.53 mg/L in Sulphur watershed and 0.31 to 0.57 mg/L in Granger watershed.

Total Kjeldahl nitrogen median loads from the mouth of each drain were comparable from 2002 through 2004 (Figure 11B&F). Within the Sulphur sub-basins, loads from any given sub-basin variously increased, decreased or remained steady between irrigation seasons (Figure 11C). In most of the Granger sub-basins, loads changed only slightly from 2000 through 2004, except during the 2001 drought (Figure 11D). However, the load from combined sub-basins 1,2,3 increased sharply in 2002, then declined through 2004 but remained higher in 2004 than 2000.
Median yields of total Kjeldahl nitrogen from Sulphur Creek Wasteway were consistent from 2002 to 2004 (Figure 11D). During these same irrigation seasons, yields from Sulphur sub-basins increased slightly. In the Granger watershed from 2002 through 2004, yields from Granger Drain and sub-basins 5, 6, and 7 were fairly constant, while yields from the combined sub-basins 1,2,3 and sub-basin 4 increased (Figure 11H).

Fecal Coliform

From 2002 to 2004 in both watersheds, fecal coliform geometric mean concentrations no longer consistently declined, unlike from 1997 to 2001 (Figure 12A&E). During 2002 to 2004, the geometric mean varied from 160 to 633 colony-forming-units per deciliter (cfu/dL) throughout the Sulphur watershed and 213 to 1056 cfu/dL throughout the Granger watershed. The not-more-than-10%-of-all-samples concentrations were less than 2300 cfu/dL since 2001 in the Sulphur watershed, and less than 7700 cfu/dL since 2000 in the Granger watershed, except for one extreme sample in Granger sub-basin 7 in 2002 (Figure 12B&F).

All sites within both watersheds for all irrigation seasons failed to meet state water quality standards (Table 4) for fecal coliform.

Table 4. Washington State fecal coliform standards for surface waters (2004).

Fecal coliform limits (cfu/dL)		
	Geometric mean	Not-more-than-10%-of-all-samples
Granger Drain and Sulphur sub-drains	100	200
Sulphur Creek Wasteway	200	400
Cfu/dL= colony forming unit per deciliter. Number of colonies of bacteria in 3.4 oz. (100 milliliters or 1 deciliter) of water sample.		

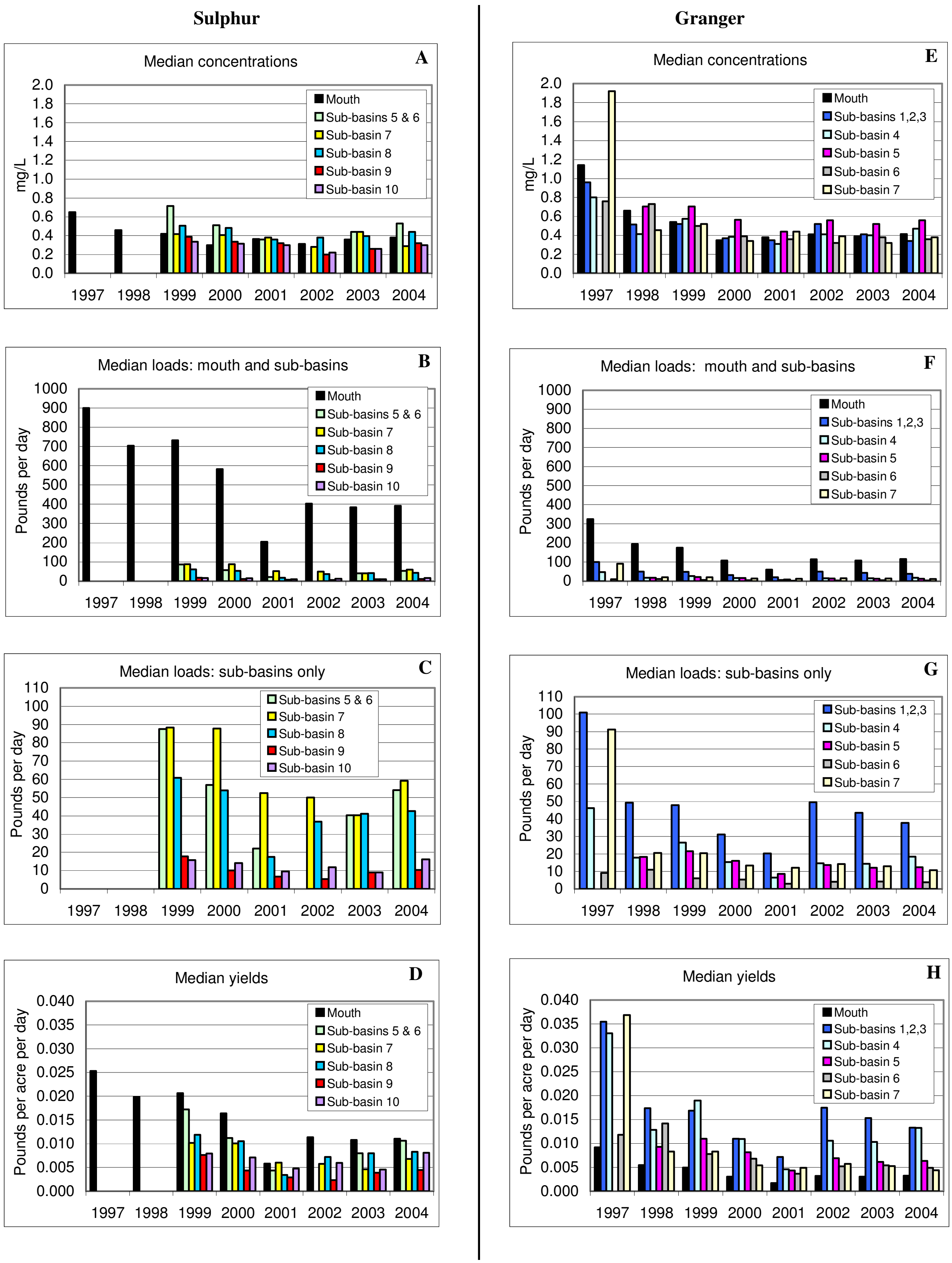


Figure 11. Total Kjeldahl nitrogen: median concentrations, loads and yields, Sulphur and Granger watersheds, 1997 to 2004 irrigation seasons.

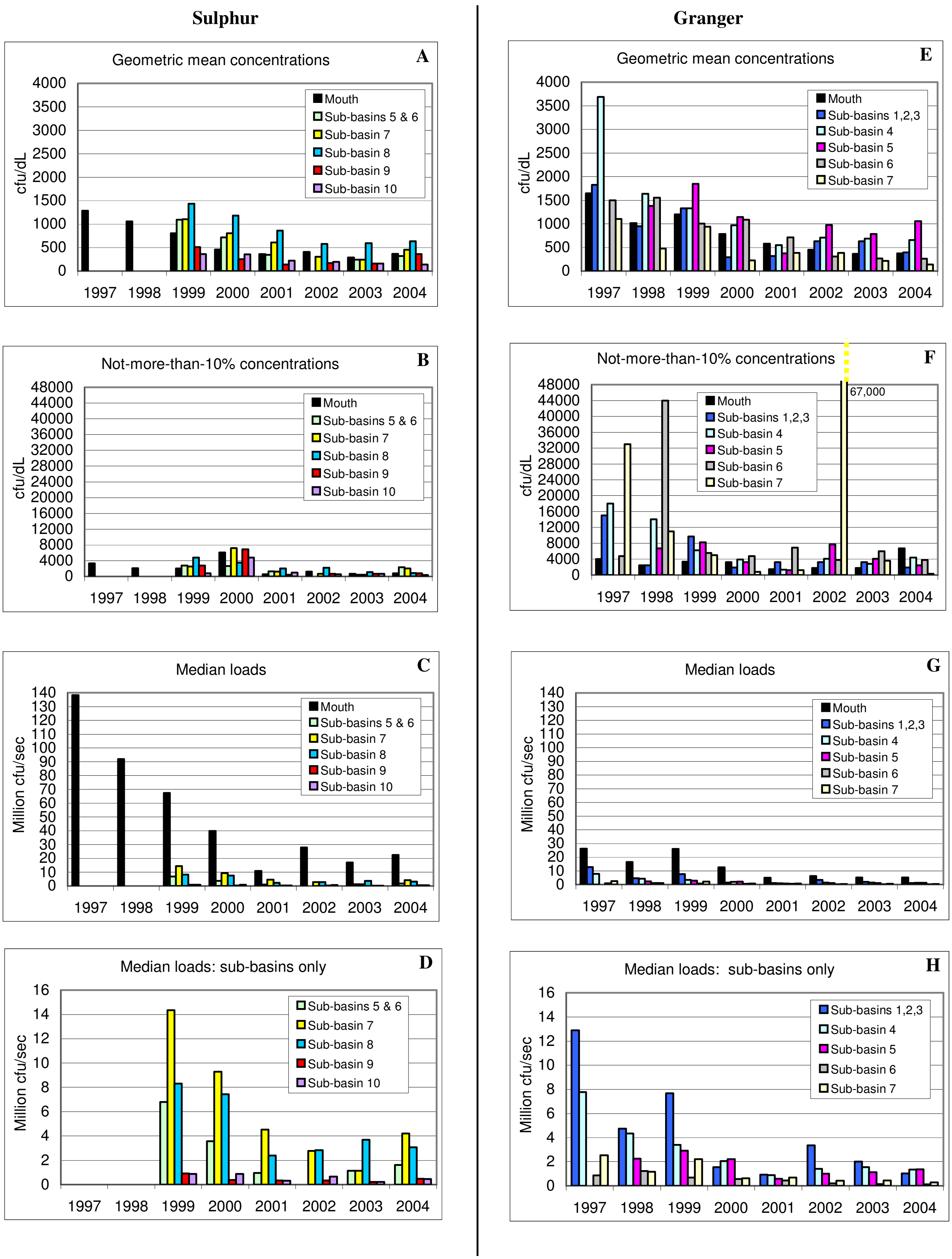
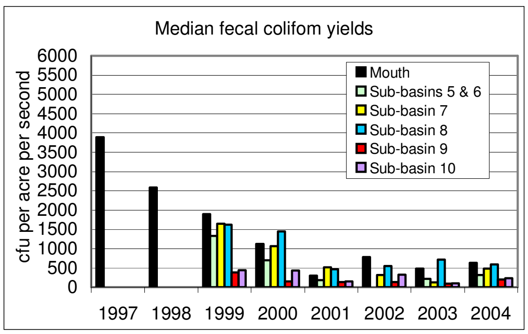


Figure 12. Fecal coliform: geometric mean and not-more-than-10%-of-all-samples concentrations, and median loads, Sulphur and Granger watersheds, 1997 to 2004 irrigation seasons.

Median loads of fecal coliform were generally less in 2004 than 2000 but the intervening irrigation seasons were variable with increased, continued decreasing, or stable loads at various sites (Figure 12 D&H). In the sub-basins of both watersheds, yields since 2000 were generally near or less than 500 cfu/acre/ second, except one to two sub-basins in the Granger watershed which sporadically had higher yields (Figure 13).

Sulphur



Granger

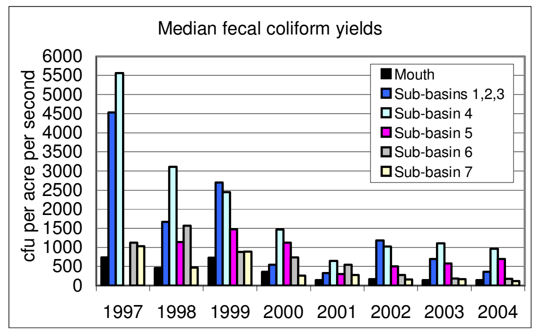


Figure 13. Fecal coliform: median yields, Sulphur and Granger watersheds, 1997 to 2004 irrigation seasons.

Non-irrigation Season

Concentrations and loads of specific constituents during the non-irrigation season -- from late October to April -- are discussed below. Data through March 2005 were available from Roza-Sunnyside Board of Joint Control for most sites, except the 2004 non-irrigation season's discharge in Sulphur Creek Wasteway for which the rating curve had not yet been updated.

Discharge

Median discharge from both drains during the non-irrigation season of 2003 and 2004 was within the range of values observed in previous years (Figure 14A&D).

Total Suspended Solids

The median concentrations of total suspended solids during the non-irrigation season varied more in Sulphur Creek Wasteway than Granger Drain but were generally less than 75 mg/L in all years in both drains (Figure 14B&E). Non-irrigation season median concentrations were higher than during the irrigation season from 2001 to 2004 in Sulphur Creek Wasteway. In Granger Drain, the non-irrigation season median concentrations were approximately 20 mg/L less than during the irrigation seasons from

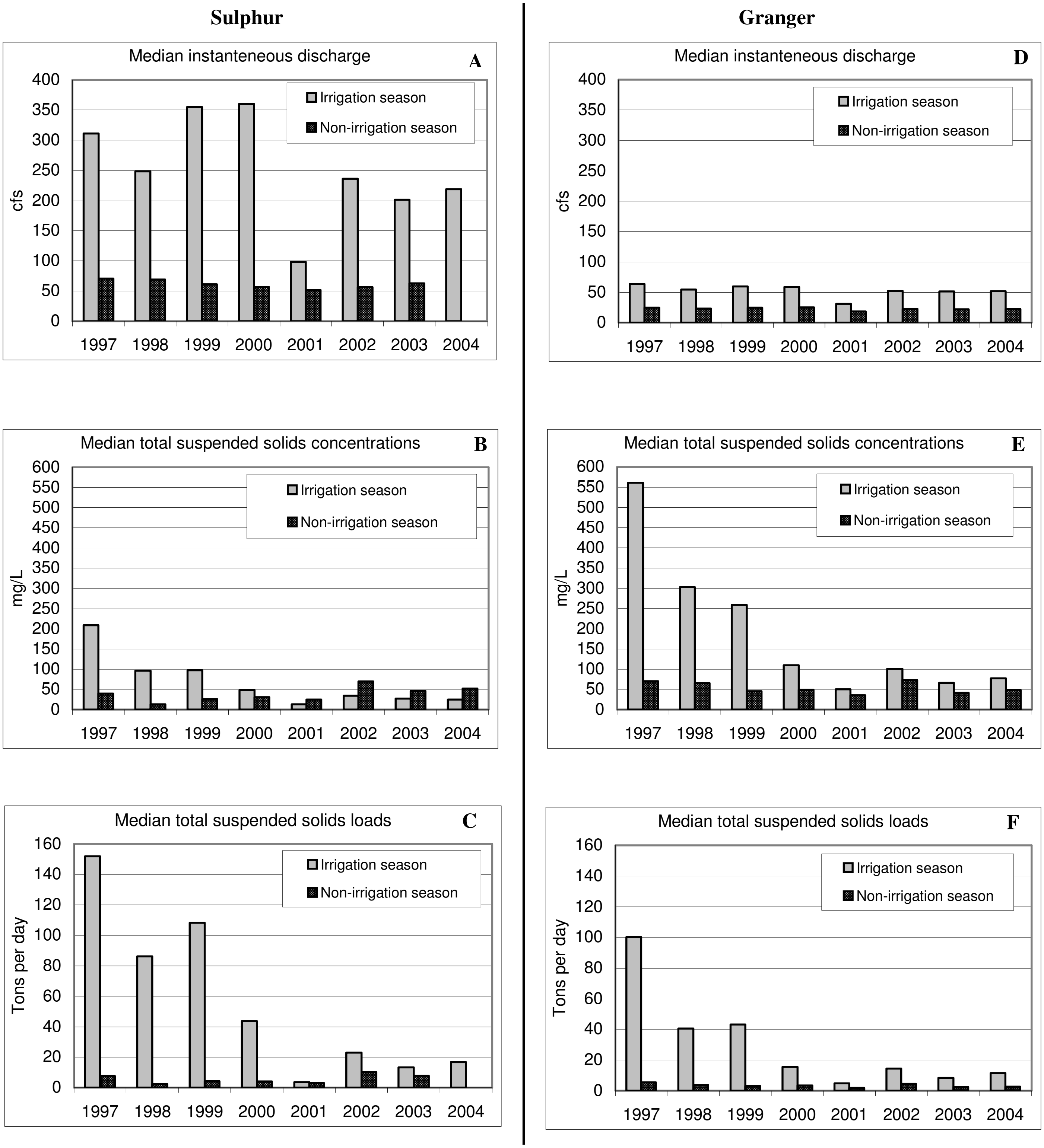


Figure 14. Irrigation season and non-irrigation season median instantaneous discharge, and median concentrations and loads of total suspended solids, Sulphur Creek Wasteway and Granger Drain, 1997 to 2004.

2001 to 2003. In contrast, from 1997 to 2000, the non-irrigation season concentrations were 50 to 500 mg/L less than during the irrigation seasons.

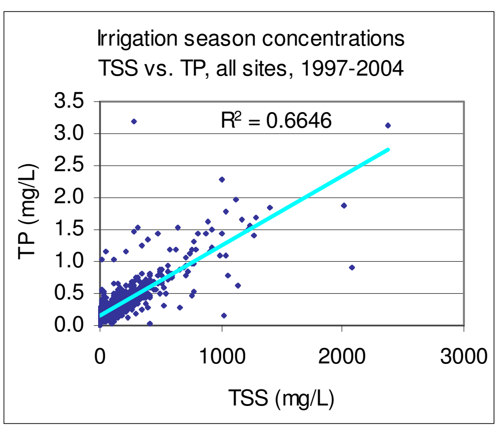
Differences in non-irrigation season suspended sediment loads between years (Figure 14C&F) reflected differences in concentrations, since discharge was nearly constant between the non-irrigation seasons.

Total Phosphorus

Since 2000, median total phosphorus concentrations in Sulphur Creek Wasteway during the non-irrigation seasons were higher than during the irrigation seasons (Figure 16A&E, next page). In Granger Drain, non-irrigation and irrigation season concentrations were comparable since 2000.

Median total phosphorus loads during the non-irrigation seasons remained less than irrigation season loads for all years, with a narrowing of differences over time reflecting the decreased irrigation season loads (Figure 16B&F, next page).

The source of phosphorus in the drains during the non-irrigation season is uncertain. To better understand the behavior of phosphorus, the relationship between total suspended solids and total phosphorus concentrations was considered (Figure 15). During the irrigation season, these two constituents were strongly correlated ($r^2 = 0.66$). For example, when total suspended solids (TSS) concentrations increased, there was a strong tendency for total phosphorus (TP) concentrations to increase as well. During the non-irrigation season, concentrations of total suspended solids and total phosphorus were not correlated ($r^2 < 0.01$). For example, as total suspended solids concentrations increased, total phosphorus concentrations tended to remain the same.



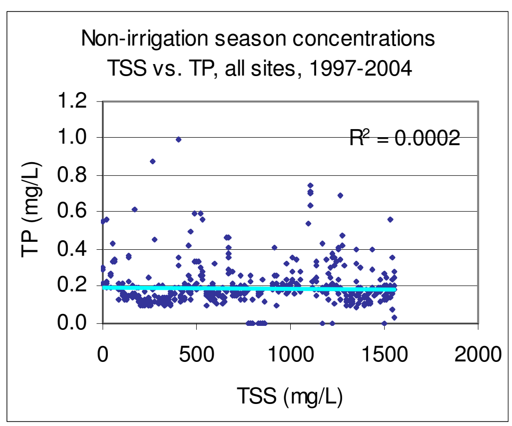


Figure 15. Irrigation season and non-irrigation season correlations between total suspended solids and total phosphorus concentrations, all Sulphur and Granger sub-basins and mouths, 1997 to 2004.

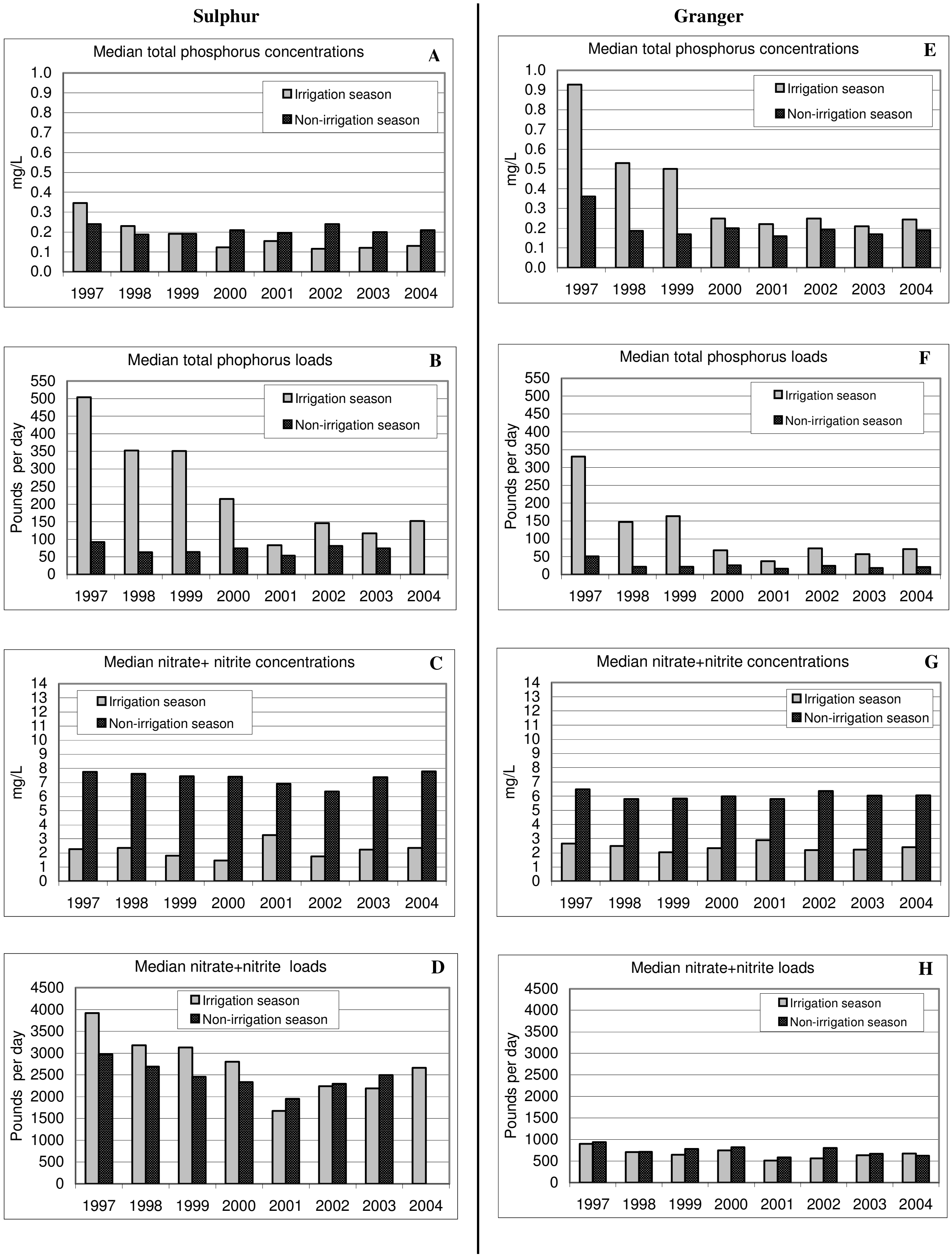


Figure 16. Irrigation season and non-irrigation season median concentrations and loads of total phosphorus and nitrite+nitrate, Sulphur Creek Wasteway and Granger Drain, 1997 to 2004.

Based on the different relationship between phosphorus and suspended solids during the irrigation and non-irrigation seasons, it is likely that phosphorus in the drains during the non-irrigation season is in the dissolved form, not bound to suspended particles. Where could dissolved phosphorus be coming from? Possibilities include groundwater, decaying vegetation, and desorption from sediment in the bottom of the drain.

Desorption would be more likely under anoxic (without oxygen) conditions. While desorption may be occurring, it is difficult to see a reason the bottom of the drains would be more anoxic during the winter than summer.

Decaying vegetation is certainly one possible source of phosphorus but if that were the primary source, we might expect to see an initial increase in the fall once the plants die, followed by a gradual decline. The temporal charts for Sulphur sub-basins (Figure 22) do not show this pattern.

It seems more likely that throughout these watersheds roughly 0.15 to 0.25 mg/L total phosphorus is entering the drains throughout the year in groundwater, with additional phosphorus entering the drains from on-farm runoff during the irrigation season in higher concentrations but bound to suspended sediment. This possibility is supported by the distribution of the data (Figure 17), with similar medians during each season yet much higher variability during the irrigation season.

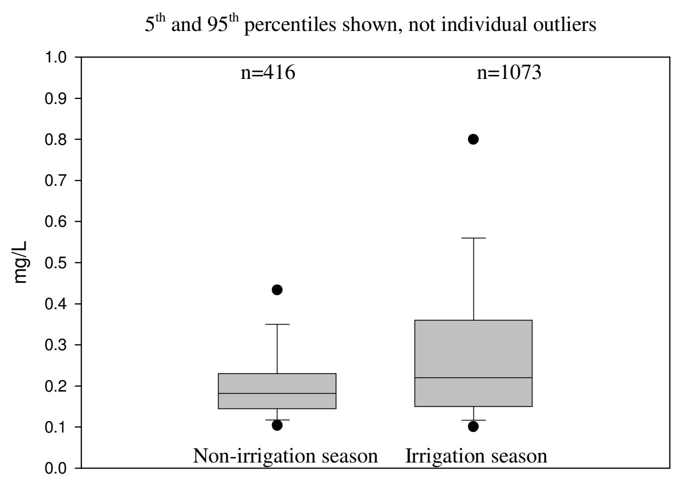


Figure 17. Total phosphorus concentrations in Sulphur and Granger sub-basins and mouths, non-irrigation seasons and irrigation seasons, 1997 to 2004.

Nitrate

Median nitrate concentrations and loads in both drains followed the same pattern as previous years: much higher nitrate concentrations during the non-irrigation season but comparable irrigation and non-irrigation season loads (Figure 16C,D,G,& H).

During the non-irrigation season, water in the drains consists almost entirely of groundwater, with elevated nitrate concentrations. During the irrigation season, irrigation return flows with lower nitrate concentrations enter the drains, diluting the groundwater. The load remains comparable year-round because discharge during the non-irrigation season decreases, so even though concentrations are higher, the amount of nitrate leaving the drains remains fairly steady.

Total Kjeldahl Nitrogen

In Sulphur Creek Wasteway, median total Kjeldahl nitrogen concentrations were higher during the non-irrigation season than the irrigation season each year (Figure 18A&E). In Granger Drain, non-irrigations season concentrations were lower than the irrigation season during 1997, 1998, 1999, and 2001 but were equivalent in 2000, 2002, and 2003. For unknown reasons, non-irrigation season concentrations were higher -- in some years much higher -- in Sulphur Creek Wasteway than Granger Drain in all years except 1997.

Non-irrigation season median loads were lower than during the irrigation season in both drains for all years except Sulphur Creek Wasteway in 2001 when loads were equivalent (Figure 18B&F).

Fecal Coliform

In Sulphur Creek Wasteway, non-irrigation season median fecal coliform concentrations were lower than during the irrigation season from 1997 to 1999 and in 2004. Median concentrations were similar during the irrigation and non-irrigation seasons in 2000 to 2003 (Figure 18C&G). In Granger Drain, non-irrigation season concentrations were lower than irrigation season concentrations in each year.

The number of non-irrigation seasons in compliance with the state fecal coliform standard varied widely throughout the watersheds (Table 5).

Table 5. Number of non-irrigation seasons in compliance with state standards from 1997 to 2004.

Granger Drain Watershed	Geometric mean standard	Top 10% standard	Sulphur Creek Wasteway Watershed	Geometric mean standard	Top 10% standard
Sub-basin 7	7	3	Sub-basin 5&6	2	1
Sub-basin 6	1	0	Sub-basin 7	2	0
Sub-basin 5	8	8	Sub-basin 8	4	0
Sub-basin 4	2	2	Sub-basin 9	3	1
Sub-basins 1,2, 3	3	1	Sub-basin 10	5	3
Mouth	0	0	Mouth	0	0

Median loads in both drains during the non-irrigation season were less than the irrigation season in each year (Figure 18D&H).

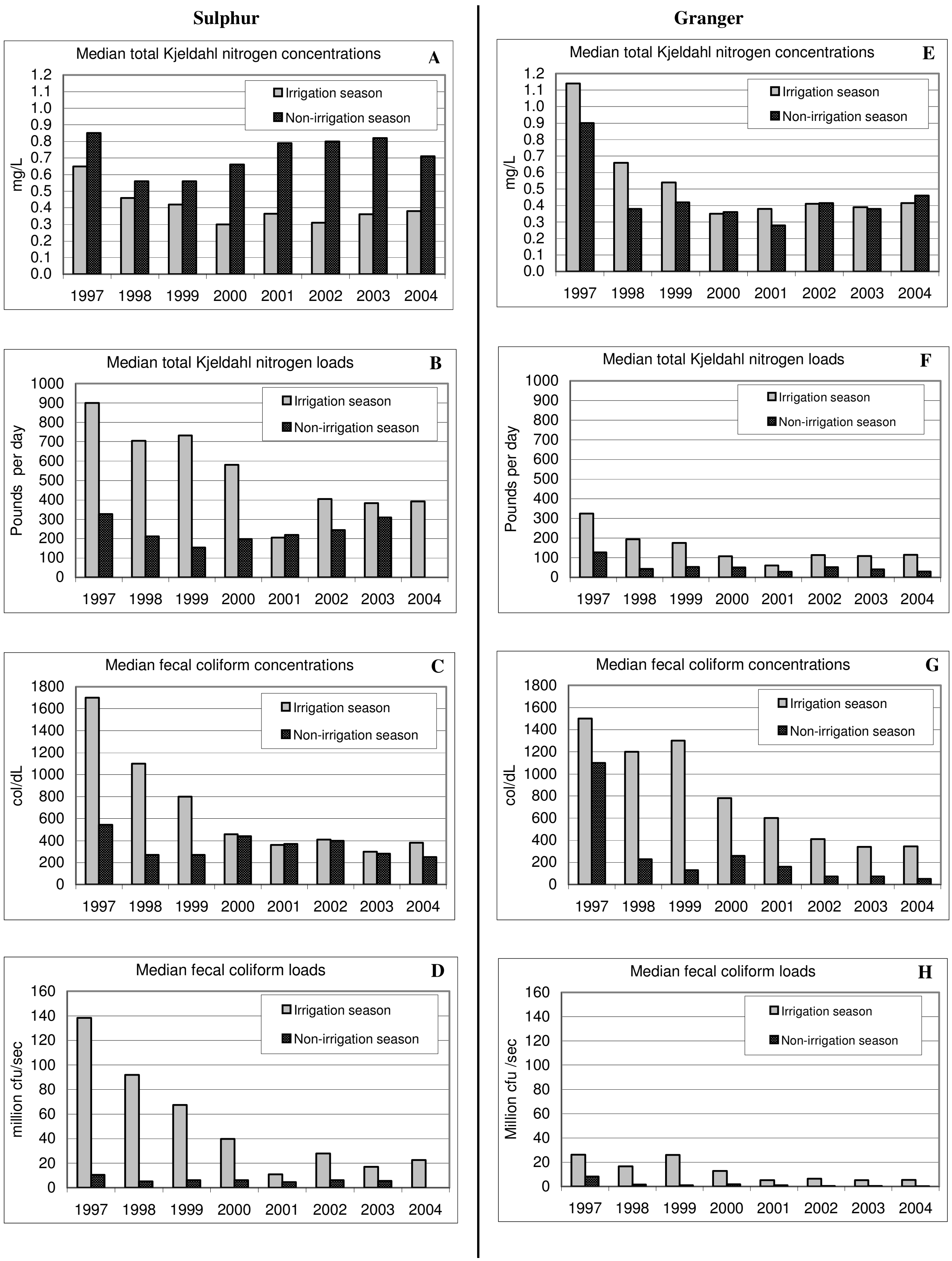


Figure 18. Irrigation season and non-irrigation season median concentrations and loads of total Kjeldahl nitrogen and fecal coliform, Sulphur Creek Wasteway and Granger Drain, 1997 to 2004.

Sulphur Sub-basins

Unlike Granger Drain, Sulphur Creek Wasteway receives spill water from the canals and urban point and non-point sources. Because of this, it is difficult to directly compare results with Granger Drain. Since the relationship between non-irrigation and irrigation season concentrations was different in Sulphur Creek Wasteway than in Granger Drain, four sub-drains in the Sulphur watershed were evaluated for their non-irrigation season versus irrigation season concentrations to see if the sub-basins followed the same pattern as the mouth of Sulphur Creek Wasteway. The monitoring site for combined sub-basins 5&6 was not evaluated because there were only two years of non-irrigation data available.

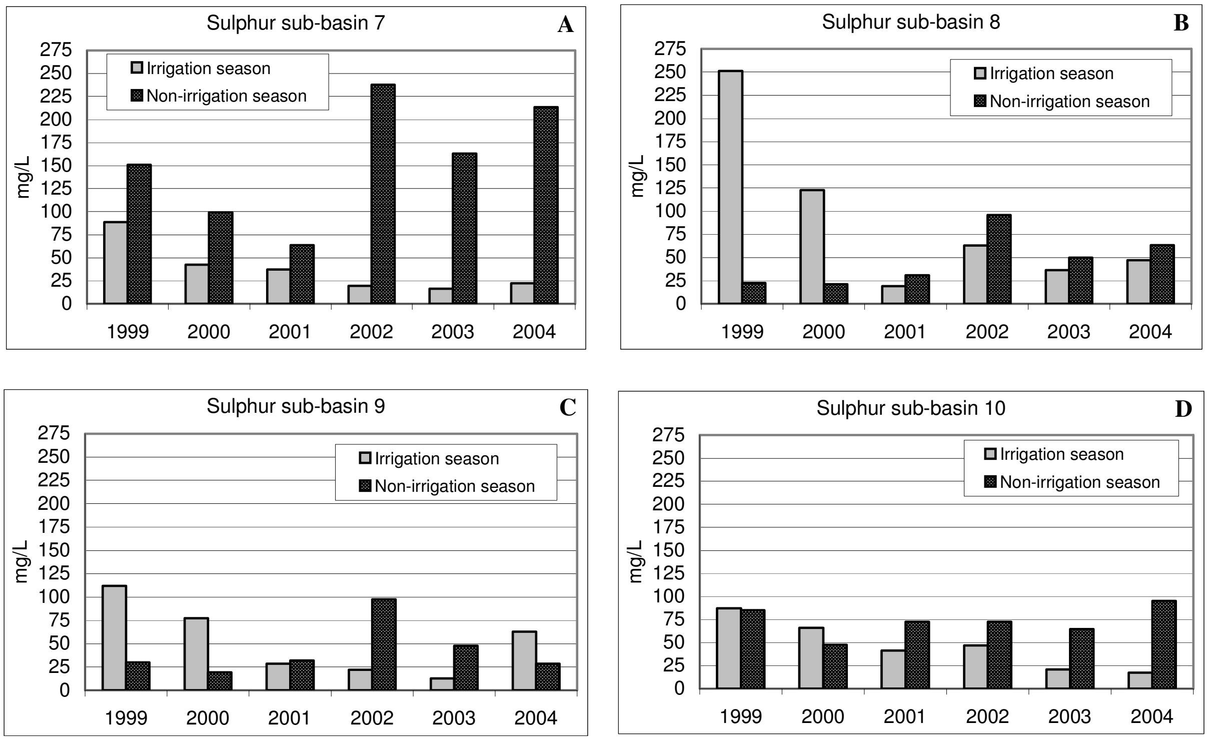
For total suspended solids, sub-basins 8, 9, and 10 followed the same pattern as the mouth of Sulphur Creek Wasteway, with non-irrigation season concentrations exceeding irrigation season concentrations beginning in 2001 and nearly every year since then. Sub-basin 7 had substantially higher non-irrigation season concentrations than the other sub-basins. Sub-basin 7 also had non-irrigation season concentrations higher than irrigation season concentrations every year since monitoring began in 1999 (Figure 19A-D)). Beginning in 2002, total suspended solids concentrations in sub-basin 7 increased considerably with no immediately obvious reason. One suggested cause, the construction of the WalMart distribution center in that sub-basin, seems unlikely to explain the increase, since that facility has an on-site water storage pond for run-off collection built for a 25-year storm event and has no permit to discharge to the irrigation return drain.

Total phosphorus concentrations in sub-basins 8, 9, and 10 also shifted to a pattern of higher non-irrigation season concentrations than irrigation season concentrations beginning in 2002, 2001, and 2000, respectively (Figure 19F-H). As with total suspended solids, median non-irrigation season concentrations of total phosphorus in sub-basin 7 exceeded irrigation season concentrations since 1999.

The seasonal pattern of total Kjeldahl nitrogen (TKN) concentrations in the sub-basins was markedly different than the mouth of Sulphur Creek Wasteway. This fits well with an earlier analysis of sources, in which roughly half of the TKN load in Sulphur Creek Wasteway came from the sub-basins and the other half from canal spills and urban sources.[3] At the mouth, median TKN concentrations during the non-irrigation season were higher each year than irrigation season concentrations, and much higher since 2000. In the sub-basins, the relationship was more variable (Figure 20A-D). In sub-basin 7, the non-irrigation season concentrations were higher than irrigation season in only three years, in sub-basin 8 two years, sub-basin 9 four years, and sub-basin 10 three years -- often only slightly higher.

[3] *Conservation Practices and Water Quality Trends in Sulphur Creek Wasteway and Granger Drain Watersheds, 1997 to 2002*, South Yakima Conservation District in collaboration with the Roza-Sunnyside Board of Joint Control, December 2004, page 15.

Median total suspended solids concentrations



Median total phosphorus concentrations

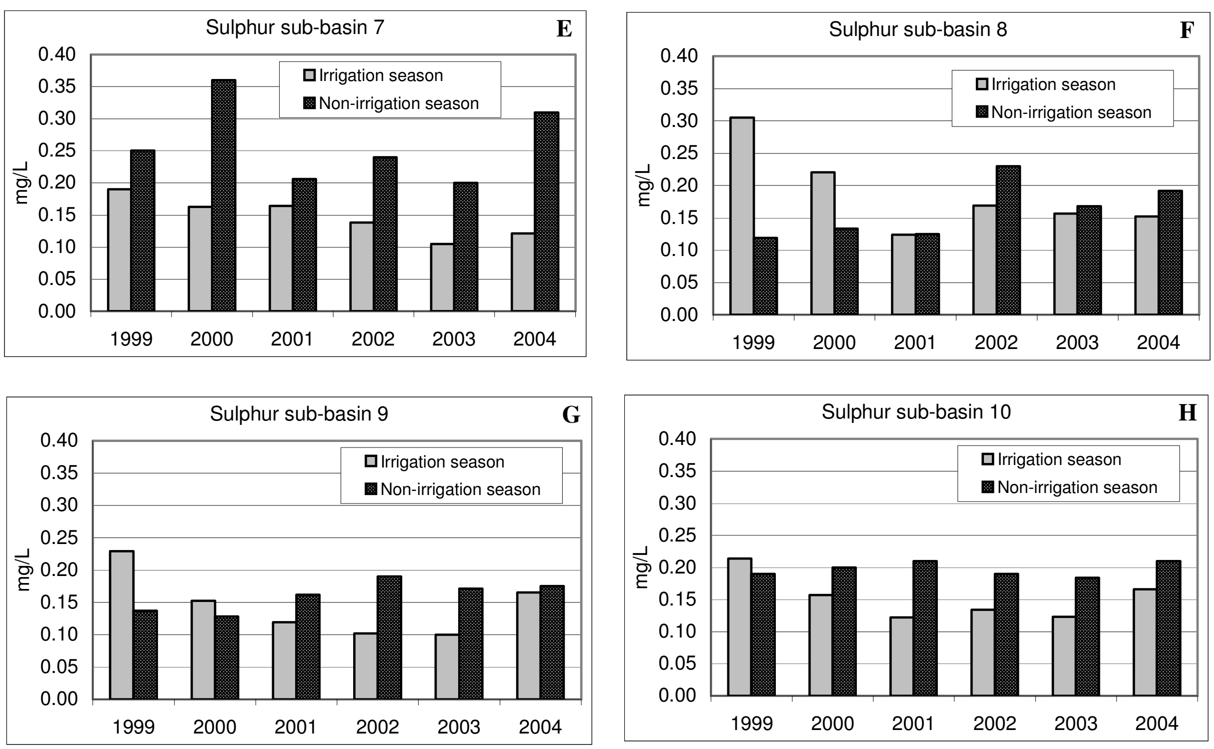


Figure 19. Sulphur sub-basins 7, 8, 9, and 10 irrigation and non-irrigation season median concentrations of total suspended solids and total phosphorus.

Fecal coliform concentrations at the mouth were much higher during the irrigation season than the non-irrigation season until 2000, when declining irrigation season concentrations became comparable to non-irrigation season. In contrast, in the sub-basins the irrigation season concentrations remained higher than the non-irrigation season concentrations in most sub-basins in most years (Figure 20E-H).

To attempt to better understand potential sources of suspended sediment, phosphorus, total Kjeldahl nitrogen, and fecal coliform to the sub-drains during the non-irrigation season, changing concentrations throughout the non-irrigation season were considered (Figures 21, 22). There was no obvious consistent temporal pattern to the varying concentrations of these constituents in three of the sub-basins.

In sub-basin 7, however, in most years concentrations of total suspended solids and total phosphorus began low in November, increased to their highest concentrations in January, then declined through March. This was roughly similar to average (mean) and maximum monthly precipitation patterns near Sunnyside (Figure 20). Yet it is unclear how or if sub-basin 7 could be more strongly influenced by precipitation than the other sub-basins. Total Kjeldahl nitrogen and fecal coliform concentrations in sub-basin 7 did not follow this or any other obvious pattern.

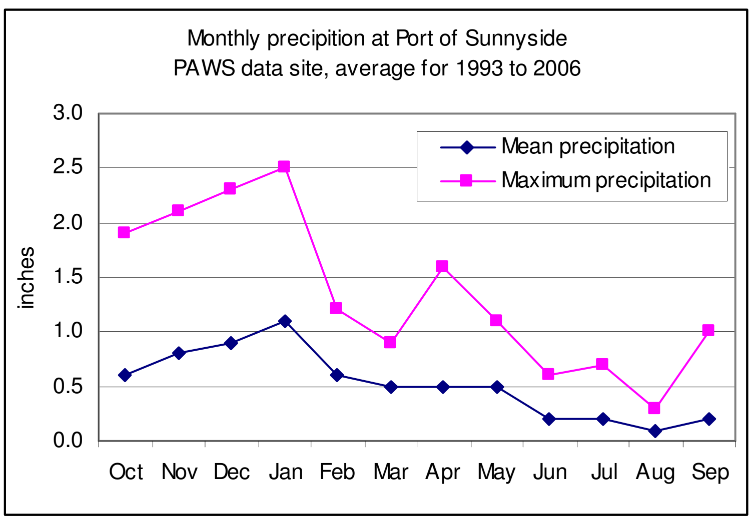
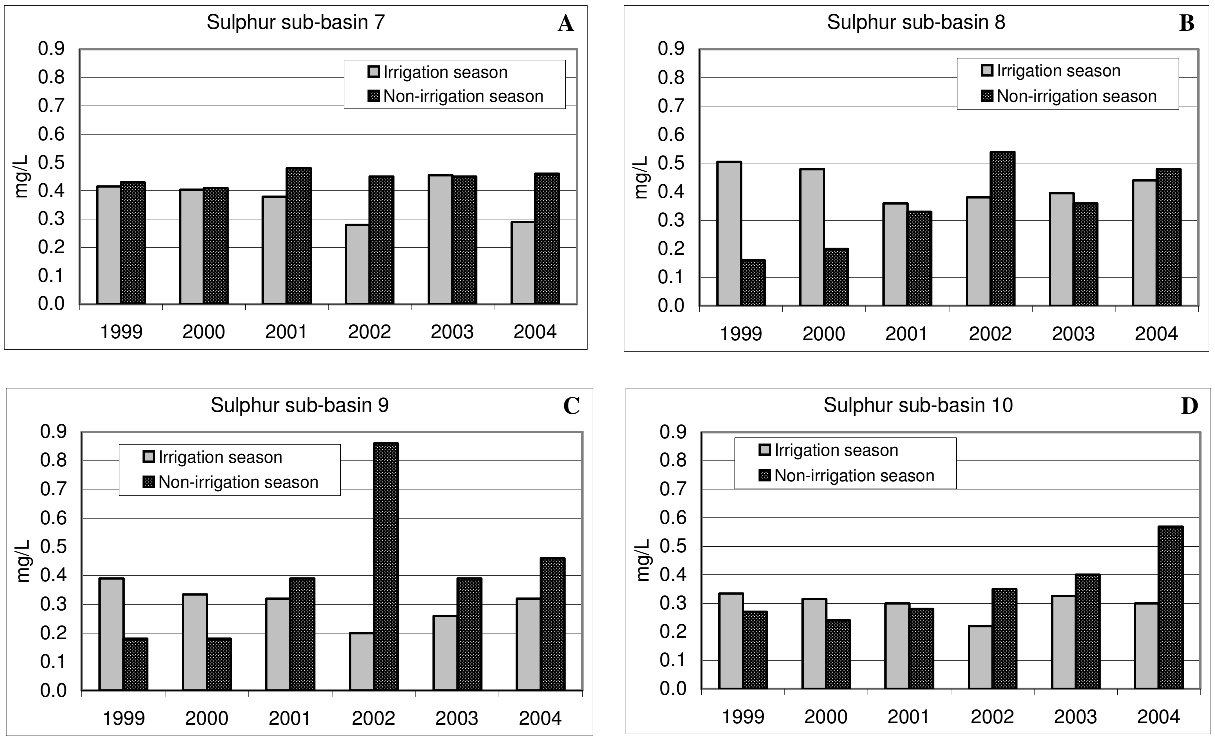


Figure 20. Average monthly precipitation near Sunnyside, 1993 to 2006.

Median total Kjeldahl nitrogen concentrations



Median fecal coliform concentrations

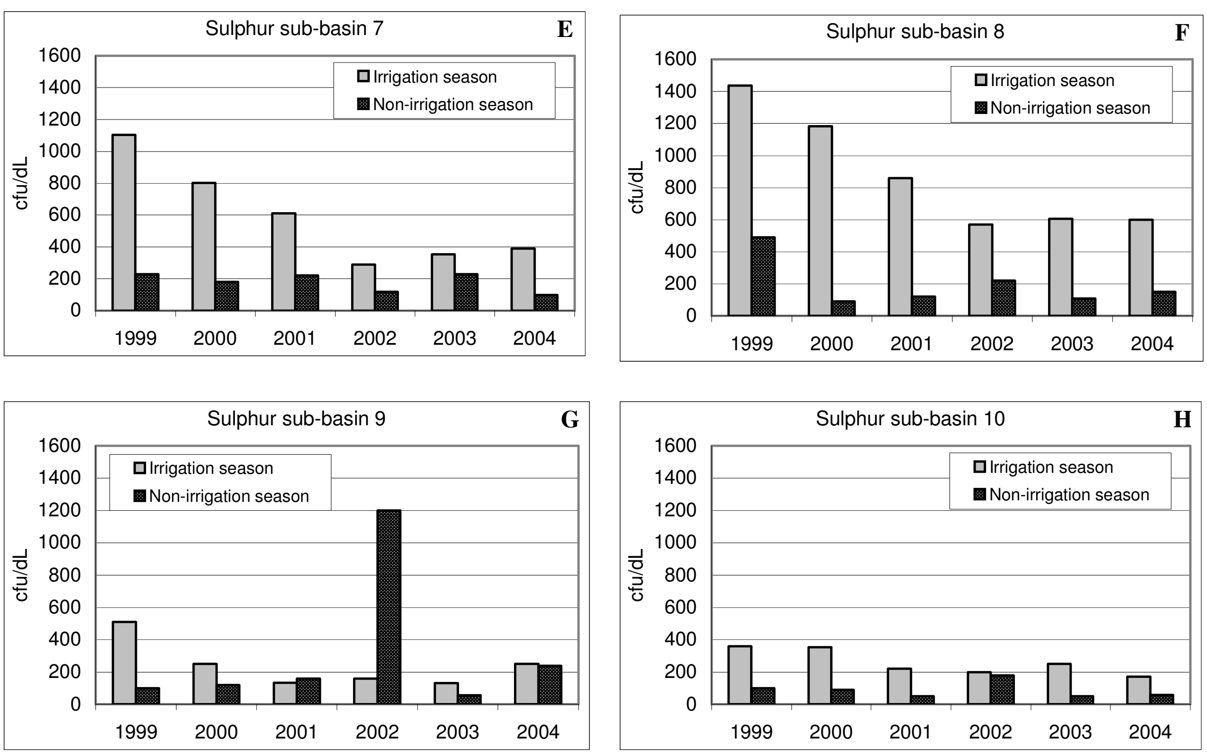
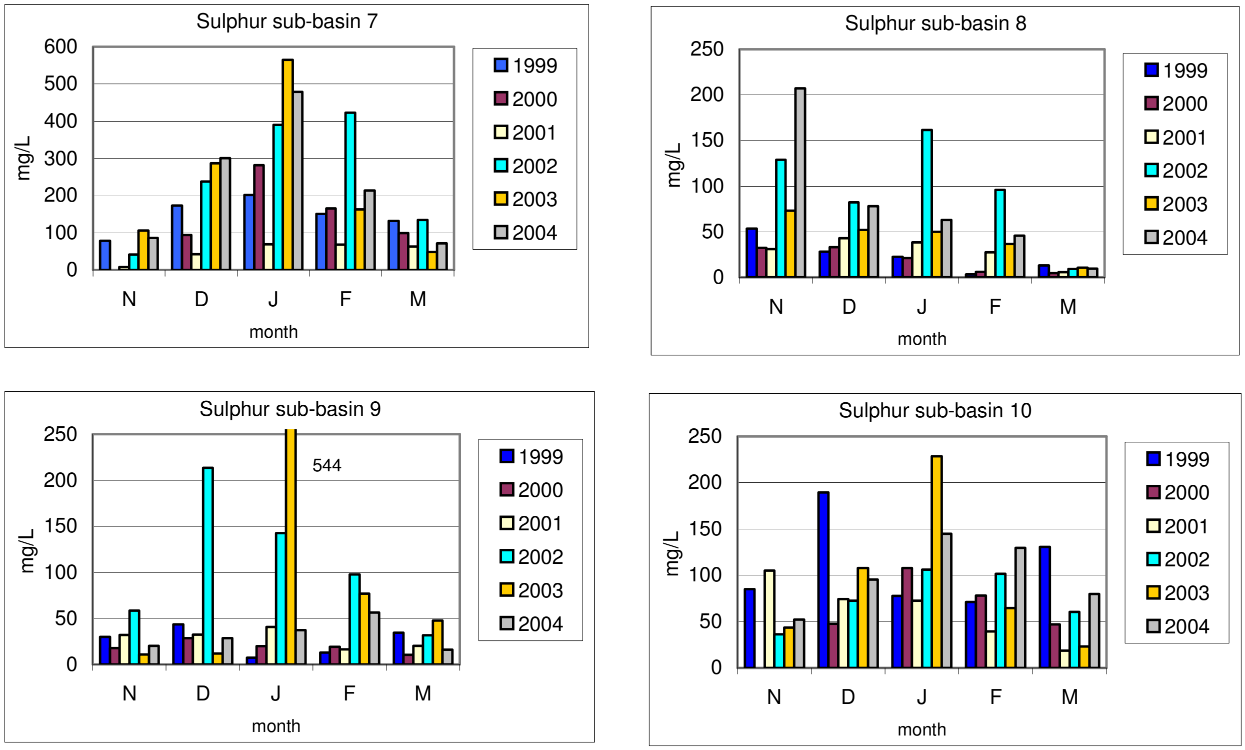


Figure 21. Sulphur sub-basins 7, 8, 9 and 10 irrigation and non-irrigation season median concentrations of total Kjeldahl nitrogen and fecal coliform.

Total suspended solids concentrations



Total phosphorus concentrations

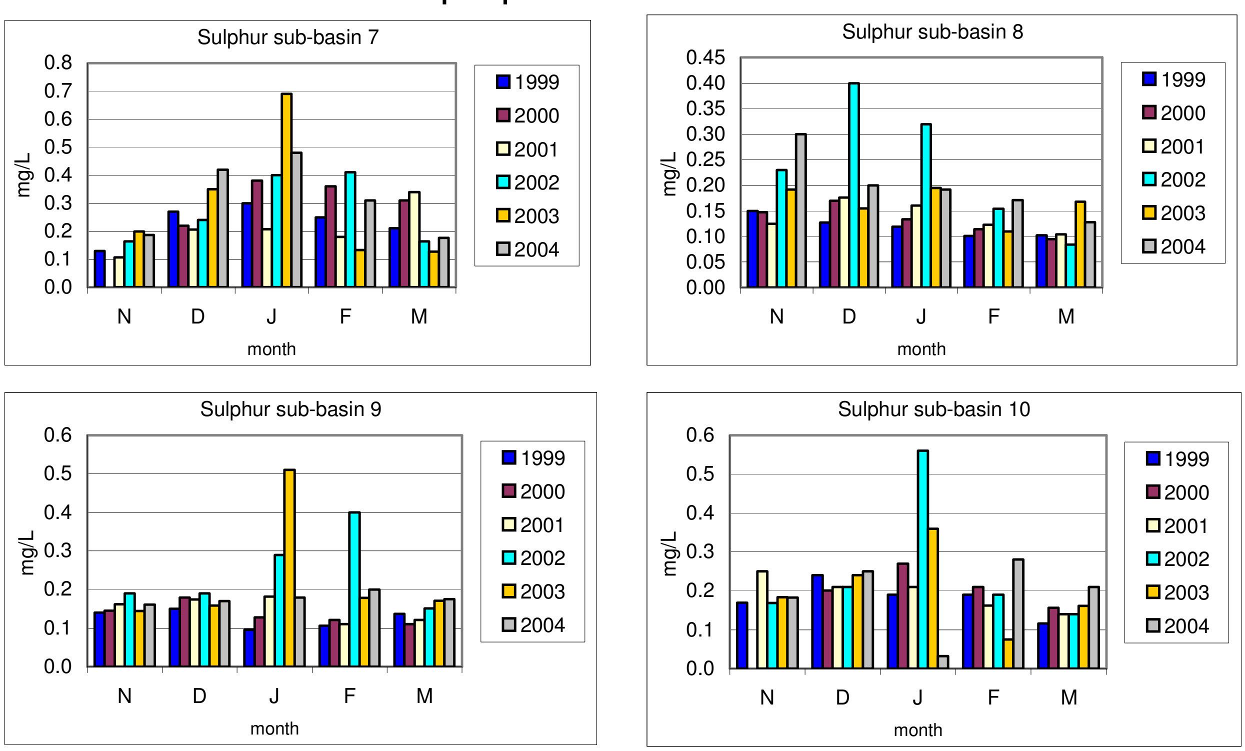
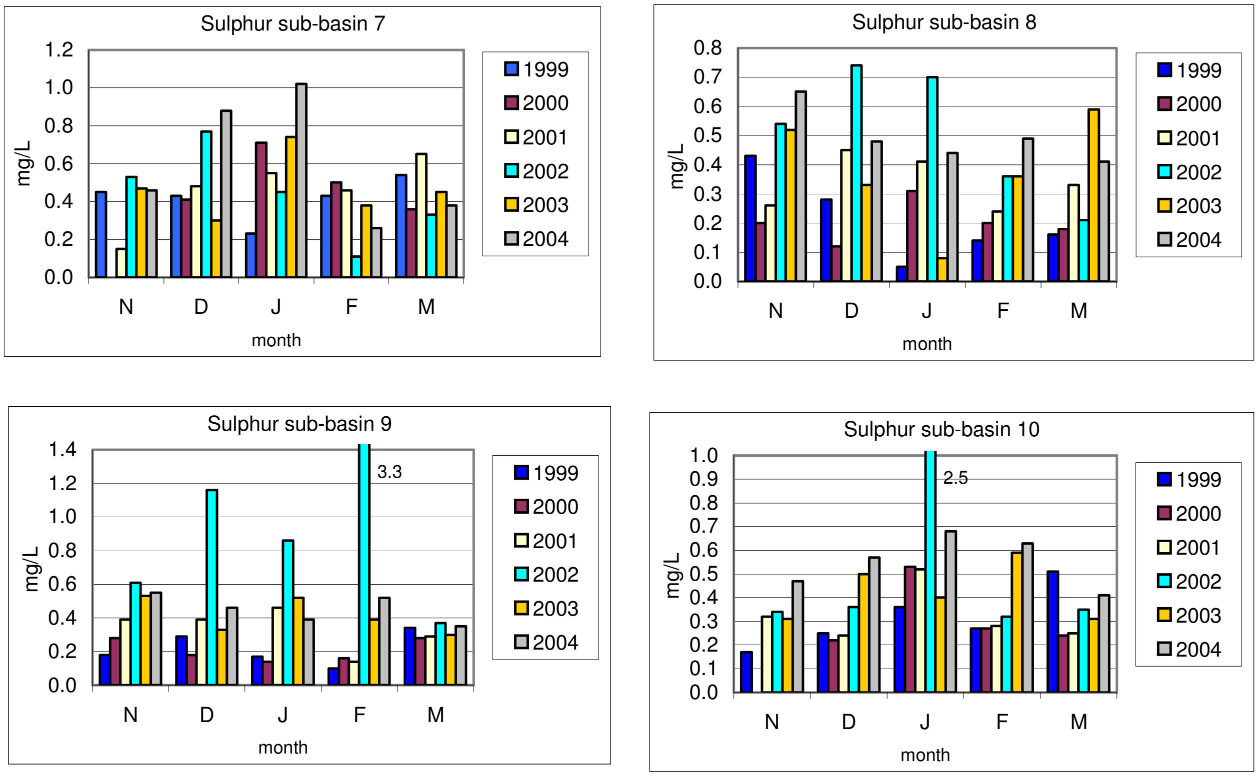


Figure 22. Non-irrigation season concentrations of total suspended solids and total phosphorus in Sulphur sub-basins 7, 8, 9, and 10.

Total Kjeldahl nitrogen concentrations



Fecal coliform concentrations

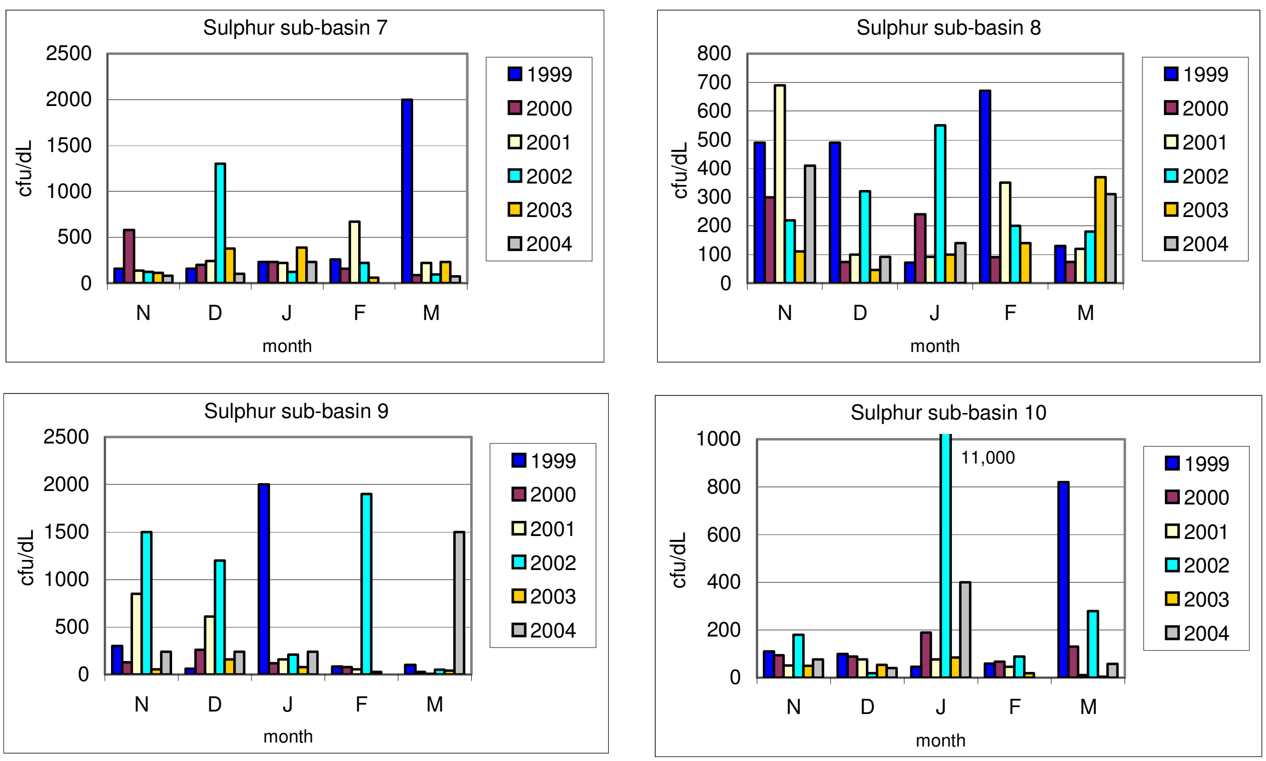


Figure 23. Non-irrigation season concentrations of total Kjeldahl nitrogen and fecal coliform in Sulphur sub-basins 7, 8, 9, and 10.

Discussion

The trends in concentrations from 1997 to 2004 of total suspended solids, total Kjeldahl nitrogen, and fecal coliform in Sulphur Creek Wasteway and Granger Drain were significantly downward. Within the overall trend is a concerning pattern – a distinct slowing of the rate of improvement since 2000. Based on widespread patterns throughout the watersheds of decreased rates of improvement, increased number and frequency of years and sites with worsening conditions (although often only slightly worse), and the decreased variability in concentrations at any given site, it is possible the current multi-agency effort to assist landowners in reducing on-farm runoff may be nearing the limits of its effectiveness.

In Granger Drain, where irrigation season concentrations continue to be higher than non-irrigation season concentrations, the potential for improvement still exists. But the continued non-attainment of the turbidity TMDL goal, despite so very much effort by so many different landowners and organizations, raises many questions, such as: If continued improvements are aggressively pursued, is in-stream treatment a viable alternative to voluntary BMP implementation? What would be the cost of increased efforts or efforts entirely different in nature and scope to achieve the TMDL goal? What would be the benefit? How important is meeting the TMDL goal to the health of the Yakima River?

In some ways, the questions for Sulphur Creek Wasteway are even more difficult. When the irrigation season concentrations of total suspended solids and phosphorus are <u>less than</u> the non-irrigation season concentrations, as is the situation in the Sulphur Creek Wasteway watershed in recent years, it is difficult to even imagine strategies that could continue to improve water quality since we know so little about sources of these constituents during the non-irrigation season. Yet Sulphur Creek Wasteway continues to be the single largest source of nitrogen and second-largest source of phosphorus to the lower Yakima River (excluding the Roza and Chandler power returns) and continues to violate the state fecal coliform standards. Further improvements are needed but no obvious solutions present themselves.

Conclusions

Despite continued implementation of soil and water conservation practices in these watersheds, water quality improvements have slowed, become intermittent or, in some sub-drains, nonexistent. Only fecal coliform concentrations have continued to consistently decline in recent years. Reasons for the slower rate of progress are unknown. At least one possible reason is the diminishing rate of return common to many environmental improvements.

The slowing rate of improvement combined with continued non-attainment of the TMDL goal for turbidity, continued violation of state standards for fecal coliform, and continued significance of nutrients discharged from these drains into the Yakima River raise many difficult questions for future consideration.